

Bk. 5

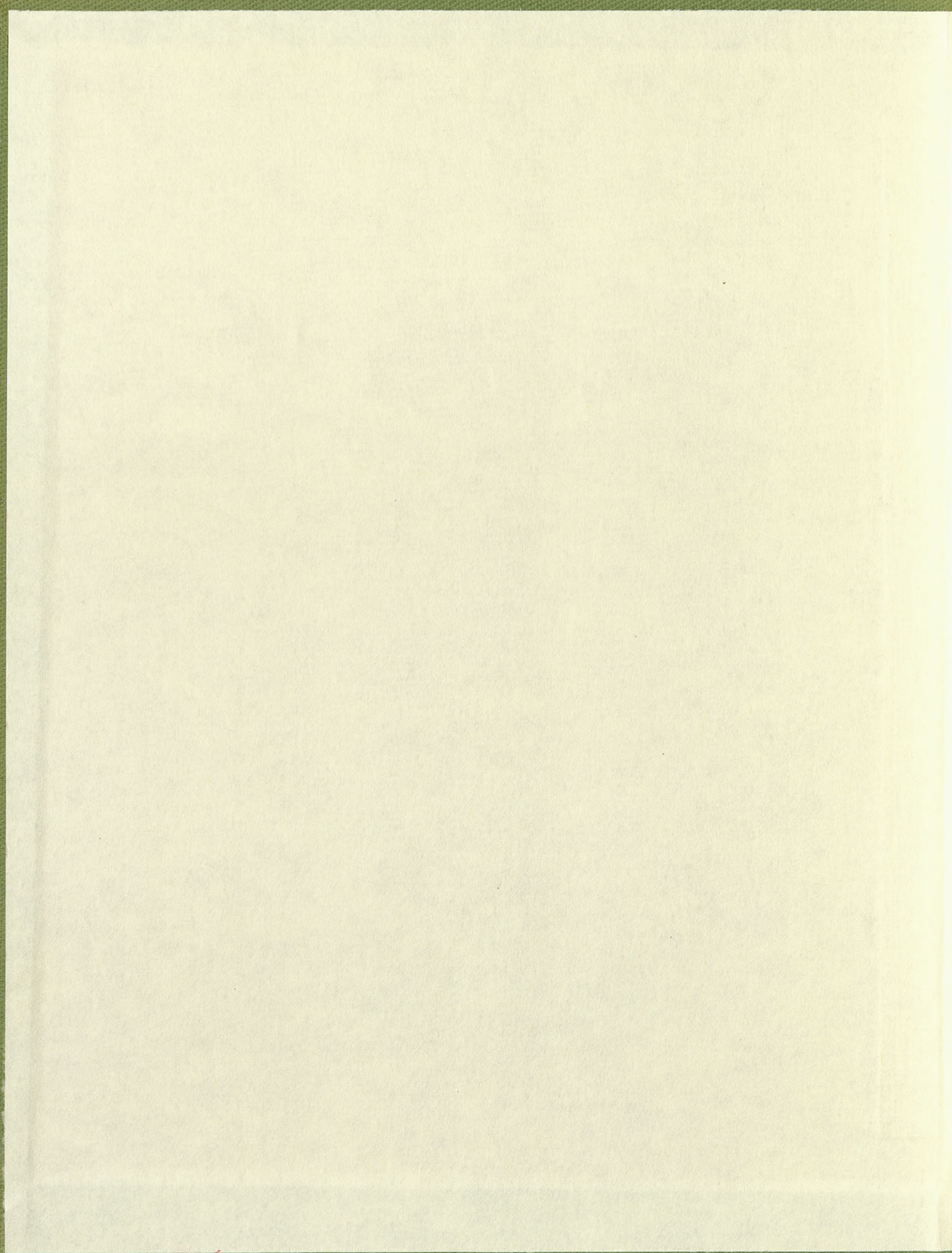
W. RALL

5

# RECORD

7530-222-3525  
FEDERAL SUPPLY SERVICE  
(GPO)

5



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9/18/64

Book 5

Continuation of Research Diary

Book # ran from 3/11/64 - 9/17/64

9/18/04  
Book 5  
Continuation of Book 5

Book 5 from 3/11/04 - 9/17/04

# Summary of Contents

7/21/64 Summary of contents to computer, that were  
8/17/64 and again on 9/18/64, which were  
very close to original ones suitable for publication.

64794 882748 Computer 35436 p. 90 of Rule 4  
33434 p. 84 of Rule 4  
This is a copy of handwritten book the pipe.

8/27 8/27/64 - 8/27/64 for pgs 7-14  
To do this, I will include handwriting  
The number of hours should go back up to 10.  
I will include the report of C. K. Hoffman.

8/27/64 Summary of contents for pgs 7-14  
Handwritten notes to us. WE 5-1 people in  
C-2, 5, 6, 7, 8, 9, 10

8/28 8/28/64 37 pgs. hand E.C. = 0.1 x hand E.C.  
Handwritten for us, but not larger 9-10.  
Notes, try .05 for this

~~64794 882748 Computer 35436 p. 90 of Rule 4~~

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33434 p. 84 of Rule 4  
This is a copy of handwritten book the pipe.

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This is a copy of handwritten book the pipe.

Summary of Contents



9/21/64

Summarize and review the computations that were set up 9/17/64 and run on 9/18/64, which are getting close to optimal runs suitable for publication.

64794.8837 & 8 compare with 35 & 36 p. 90 of Book 4  
33 & 34 p. 84 of Book 4

This is an attempt at decremental dendritic spike.

→ C  
• 8837 The inhibition was too strong for cpts 7-14  
note also that axonal spike overshoots too strongly.  
This means that ROUTC should go back up to 10.  
and ~~will~~ make the present amount of C less effective.

∴ for 39 Try ROUTC=10, and ~~C=0.5 for cpts 7-14~~  
also reduce AFPOS to .08 NEJ=1 for cpts 4-14  
C=.4, .5, .6, . . . . . 1.4

• 8838 differed from 37 only in having I.C. = 0.1 in dendrites.  
This made them fire earlier, but not bigger spikes.  
next time, try .05 for this

New Series to be 8851 & 52. CRT for a production run

64794.8841 NSD=5 Active Descending I.C. Blocked  
53 " " double I.C.  
54 total same with USA=5, USD=200, NSTEP=10

55 old 43 with NSD=10, but ↑ & doubled I.C.

64794.8842 NSD=5, Passive Ascending I.C.  
44 10 needs more ROUTB & French  
56-59 ROUTB=50 I.C. & USA=5, USD=200.  
DT=.02

9/21/64

Summarize and review the computations that were set up 9/17/64 and run on 9/18/64, which are being done to obtain our estimate for publication.

64794.883748 capex with 35436 p. 90 of book  
33434 p. 84 of book  
This is an attempt at determining the value.

8837 The initiation was too strong for the 1-14

into about equal size over the two periods.

Thinks that RDTC should be back up to 10.

and will make the present amount of C. 10000000

∴ for 37 Trp RDTC=10, and C=0.2 for 37 14

also reduce AP 902 to .08 ME 34

C=0.2, I.C.=0.14

8838 diff from 37 only in heavy I.C.=0.1 in initiation.

This is then for earlier, but not later values.

values, try .05 for this

~~Now series take 8831 8832~~

64794.8841 K=ND=2 Active Financing I.C. 10000000

33 " " 10000000 I.C.

34 Total amount with V=2, VSD=200, VSDI=100

35 Old H3 with V=10, 12, 10000000 I.C.

64794.8847 H2D=2, Passive Financing I.C.

10000000

36 - 20 - 20

37 - 20 - 20

9/21/64

Series 64794. 8741, 23 &amp; 4 cooler kinetics

.8741 NJD=5 active I.C. : 2, .16, .12, .08, .04, 0  
 got some delay & then almost synchronous spikes  
 increase by 20%  
 \* also got reflected orthochromic

.8742 (5) passive I.C. : 2, .3, .4, .4, .4, .3  
 main spikes strong pretty good but  
 got a second spike.  
 need more quench or ROOT B -  
 make ROOT B = 40.

.8743 NJD=10 Active  
 Pretty good (slight reflection in (3))

.8744 (10) Passive pretty good but needs  
 more quench

Setup as 45, 46, 47, 48

in each, increase ROOT B to 40.

NSTEP to 15

USA = 5.

USD = 200.

NPLT = 3

LJZPLT = 3

IFTEST = 103111

for  $NJD=10$  get 112

for  $NJD=5$

estimate that computation of  $(NT=41)(NSTEP=20)$  = 90 sec  
table 5 sec  
~~3 plots~~ 95

get 120 for  $NJD=10$   $NZ=14$   
for  $NJD=5$   $NZ=9$

Three plots take 18 ~~minutes~~ secs

IFTEST = 103111 should cost  $\approx$  50 secs

45 for  $NJD=5$

65 for  $NJD=10$

$\therefore$  estimate a total of about 160 secs for a run with  $NJD=5$   
205 secs  $\approx$  10

for  $NT=41$ ,  $NSTEP=20$ ,  $NPLT=3$ .

However for  $NSTEP=10$ , would have the 90 for  $NJD=5$  & save 45  
~~112~~ 55

9/21/64

# Time Estimates

early guide estimates

4

Setup 64794.8851 #2 as CRT (decremental cond.)

Setup following as a Production Run

	NT	NSTEP <sub>NTD</sub>	NPLT	IFTEST 103111 in most cases	Time	Pages
64794.8853	41	20 (5)	3	220	160	10
DT=.01	54	10 (5)	3	150	120	10
	55	10 (10)	3	150	150	10
DT=.02	56	20 (5)	3	220	160	10
	57	20 (5)	3	220	160	10
	58	20 (10)	3	220	210	10
	59	20 (10)	3	220	210	10
.8745	41	15	3	180	140	10
	46	15	3	180	140	10
	47	15	3	180	180	10
	48	15	3	180	180	10
				2120	<span style="border: 1px solid black; padding: 2px;">1810</span>	110 pages
				37 min	30 min	

(continued) TRC on CRT

Page	Time	TRC	TRC	TRC	TRC
01	100	3	3	14	14
01	120	3	3	14	14
01	120	3	3	14	14
01	160	3	3	14	14
01	160	3	3	14	14
01	160	3	3	14	14
01	180	3	3	14	14
01	180	3	3	14	14
01	140	3	3	14	14
01	140	3	3	14	14
01	180	3	3	14	14
01	180	3	3	14	14

~~or~~ CERRE

742 Write Output Topl, 15, 743  
 743 Form (H CONE RESISTANCE EFFECT  
 IS SKIPPED HERE. /)

744 IF(CONE=0)  
 GO TO 899

744 IF (IFPLVE) 640, 645, 645

640 CONE=0  
 641 GO TO 696  
 645 CONE=1 646 GO TO 653

9/21/64

5

Plan to Modify WXR 794C  $\rightarrow$  WXR 795C  
By revising extracell calc & incorporating it in  
Subroutine WXR95C

Four stages

①	(1000)	without external shunt
②	(1100)	with potential divider but E slanted
③	(1110)	with significant shunt current
④	(1111)	radial re of cone

see p. 12

IFVE = 1111 means compute and tabulate all stages  
 2222 means also plot all stages.  
 1112 means plot only last stage.  
 1002 means do not tabulate 2nd & 3rd stage.

WXR95C

Dimension

(NT, NZ, KG, NG, JS, JH, ~~CORE~~ <sup>NJD, NZ</sup>)  
 (KVE, IFVE, IFPLVE, IFAB, VEF, CORE,  
 PDF, SHCF, RHOSOM, RHOGLM)

101 GO TO (704, 740, 800, 850, 899), KVE  
 704-722 same as in 794C except replace 2.5 by VEF  
 725 becomes new number of 726  
 727 becomes IFPLVE = IFVE / 1000  
~~728 IF(IFPLVE) 729, 729, 730~~  
~~729 IFPLVE = 1~~  
 738 RETURN

740 IFVE = IFVE - 1000 \* IFPLVE

741 IF(IFVE) ~~742, 742, 745~~

746 IFPLVE = IFVE / 100

~~743 IF(IFPLVE) 744, 744, 745~~

~~744 IFPLVE = 1~~

~~800~~  
~~800, 853, 853~~  
~~743 GO TO 853~~

In main prog.

Old 560 to become 551

replace 5601 with 560

in 536 replace 560 by 551

~~replace 550 ahead of 530 have~~

~~525 IF~~

→ ~~670~~ IF (IFPLVE) 531, ~~640~~<sup>659</sup>, 531

555 IF (IFPLVE - 1) 659, 659, 560

659 CALL NI#104 (ICLOCK, JLOCK)

~~660~~ Write Output Tape 15, 999, JLOCK

660 as before

661 IF (KVE) 662, 662, 666

662 IF (VEF) 663, 663, 664

663 VEF = ~~2.5~~ 3.0

664 VMIN = -VEF

665 VMAX = 1.2 \* VEF

666 ~~666~~ KVE = KVE + 1

→ 667 ~~667~~ ~~old 662~~ ~~666 not numbered~~

668 CALL WXR95C (arg)

~~670 IF (~~KVE~~ (4 - KVE) 800, 670, 670~~

668 IF (4 - KVE) 800, 668, 668



9/21/64

745 IF (PDF) 746, 746, 747

746 PDF = 0.25

747 F = PDF / (PDF + 1.)

750 like old 750 with PDF added

751 modified & with F10.5 added  
omit VMAX & VMIN

752-780 as before except } JS in place of 1  
                                      } -F " " " -0.2

781 RETURN

800 IFVE = IFVE - 100 \* IFPLVE

801 IF(IFVE) 802, 899, 802

802 IFPLVE = IFVE / 10

~~803 GOTO 745~~ ~~803 IF(IFPKVE) 804, 804, 805~~

~~804 IFPLVE = 1~~

805 IF(SHCF) 806, 806, 807

806 SHCF = 0.2

~~808 X = 1/NJD~~ 807 F = ~~SHCF~~ SHCF / (SHCF + 1.)

~~IF(IFAB) 810, 810, 818~~ 808 DO (880) KT = 1, NT

809 PA = F \* (VATZ(KT, JS) - VATZ(KT, NZ))

~~812~~ 810 DA = PA \* ~~X~~ ~~NJD~~ ~~812~~ ~~AC(JZ) = DA \* BC~~  
~~CA = DA~~ ~~818~~ JZ = NZ ~~812~~ ~~Test for CONE~~

~~815~~ DO (818) I = 1, NZ

~~815~~ 816 VATZ(KT, JZ) = VATZ(KT, JZ) - CA

~~816~~ 817 CA = CA + DA

~~817~~ 818 JZ = JZ - 1

~~818~~ IF(AB) ~~819~~, 820, 820

~~820~~ same set for B

~~830~~ CONTINUE ~~831 RETURN~~ see over

831 Write Output Tape 15, 832, SWCF

832 Format ( H Following VE Correspond to an External Slant Factor of  $F_{10.5}$  )

833 RETURN

$$= \frac{XNSD (RHOGM * RHOSOM)}{RHOGM - RHOSOM}$$

$$F = \frac{XNSD}{\frac{1}{RHOSOM} - \frac{1}{RHOGM}}$$

668  $X = \frac{X^{JD}}{NJD}$   ~~$X = \frac{X^{JD}}{NJD}$~~  NJD

669  $X^{JD} = X * XD$

670  ~~$F = \frac{X^{JD}}{(RHOSOM * RHOGM)}$~~   $F = \frac{X^{JD}}{(RHOSOM * RHOGM)}$

671 DO 672 JZ = 1, NLZ

672 BC(JZ) =  ~~$F * X$~~  (AB(JZ) - AB(JZ+1))

673 IF(AB) 674, 674, 683

674 DO 682 KT = 1, NT

~~675 DO JZ = 1, NLZ~~

675 JZ = NLZ

676 DO 678 I = 1, NLZ

677 AC(JZ) = BC(JZ) \* (VATZ(KT, JZ) - VATZ(KT, JZ+1))

678 JZ = JZ - 1

679 JZ = NLZ

680 DO 682 I = 1, NLZ

681 VATZ(KT, JZ) = AC(JZ) + VATZ(KT, JZ+1)

682 JZ = JZ - 1

9/21/64

850 IFVE = IFVE - 10 \* IFPLVE

851 IF (IFVE) 899, 899, 852

Go to 855 if possible  
no  
600 series

~~852 IFPLVE = IFVE~~

~~853 IF (RHOSOM) 854, 854, 855~~

~~854 RHOSOM = 1.3~~

~~855 IF (RHOGLM) 856, 856, 857~~

~~856 RHOGLM = 1.7~~

~~857 XD = RHOSOM - RHOGLM~~

~~858 DRHO = XD / NJD~~

~~859 ~~AB~~ RHOX = RHOGLM~~

860 JZ = NZ  
861 CUMAB = 0.

~~860 DO 866 I = 1, NZ~~

~~861 AB(NZ) = 1. / RHOX~~

~~862 RHOX = RHOX - DRHO~~

~~863 JZ = JZ + 1~~

~~864 CUMAB = CUMAB + AB(NZ)~~

~~865 JZ = JZ - 1~~

~~870 FACAB = 1. / CUMAB~~

~~871 DO 872 JZ = 1, NZ~~

~~872 AB(NZ) = FACAB \* AB(NZ)~~

~~870 CUMAB = 0.~~

~~871 DO 872 JZ = JS, NZ~~

~~872 CUMAB = CUMAB + AB(JZ)~~

~~680 IF (TAB) 681, 681, 690~~

~~681 DO KT = 1, NT~~

~~682 DO JZ = 1, NZ~~

~~683 VATE(KT, JZ) =~~

1/2/24

820 IFVE = IVE - 10 + IFPLVE

821 IF(IFE) 822, 823, 824

822 IFKVE = IVE

823 IF(RHOSOM) 824, 825, 826

824 RHOSOM = 1.3

825 IF(RHOGM) 826, 827, 828

826 RHOGM = 1.7

827 XE = (RHOSOM - RHOGM) / X

828 BRHO = XD / NSD

829 RHOX = RHOGM

830 DO 800 I = 1, NS

831 AB(I/5) = 1. / RHOX

832 RHOX = RHOX - BRHO

833 ~~25 = 25~~

834 ~~CUMAB = CUMAB + AB(NS)~~

835 ~~25 = 25 - 1~~

836 FACAB = 1. / CUMAB

837 DO 800 25 = 1, NS

838 AB(I/5) = FACAB \* AB(NS)

839 CUMAB = 0.

840 DO 850 25 = 25, NS

841 CUMAB = CUMAB + AB(25)

842 IF(ABR) 843, 844, 845

843 RI = 1. / NT

844 ~~25 = 1, NS~~

845 VATA(NT/25) =

45 26 27 28  
9 x 1 7

25 26 27 28  
9 x 1 7

25  
9 x 1 7

9/21/64 ~~682 CONTINUE~~

~~682 JZ = NZ  
683 DO I = 1, NZ  
684 AC(JZ-1) = AB~~

~~684~~  
683 IF (IFAB) , 684, 684  
684 similar for BB

694 Write Output Tape 15, 695, RHOSOM, RHOGM  
695 Form  $\left( \frac{H}{H} \right)$  following VE include  
Conical Resistances for  
RHOSOM =, F10.5,  $\left( \frac{H}{H} \right)$  AND  
for RHOGM =, F10.5 ( )  
and F =

696 RETURN

863

~~864 IF (IFVE) 245, 245, 2442  
2443  
936~~

870 DO 871, JZ = 1, NZ  
871 AC(JZ) = DA \* BC(JZ)  
872 CA = ~~AC(NZ)~~ DA  
873 JZ = NZ  
874 DO 877 I = 1, NZ  
875 VATZ(KT, JZ) = VATZ(KT, JZ) - CA  
876 CA = CA + AC(JZ-1)  
877 JZ = JZ - 1  
879 IF (IFAB) 898, 880, 880

~~883 DO~~ 1/2/10

~~882 25 = 15~~

~~883 DO I = 1, 15~~

~~884 AC(25-1) = AB~~

~~883 (AB)~~  
~~884, 885~~  
~~885~~

~~885~~ (initial instructions for)

~~885~~ (H) follow - V. 2. 2. 2.

~~885~~ = F102 (H AND

~~885~~ = F102 (1)

885 RETURN

885

870 DO 871, 25 = 1, 15

871 AC(25) = DA \* BC(25)

872 CA = ~~DA~~ DA

873 25 = 15

874 DO 875, I = 1, 15

875 VATA = (KT, 25) \* VATA (KT, 25) - CA

876 CA = CA + AC(25-1)

877 25 = 25 - 1

880 IF (FAB) 888, 880, 880

9/22/64 These cards punched today.  
Now complete

Col 7

SUBROUTINE WXR95C (NT, NZ, KG, NG, JH, JH, NJD, NLZ  
X KVE, IFVE, IFPLVE, IFAB, ~~VEF~~ CORE,  
X VEF, PDF, SHCF, RHOSOM, RHOGLM  
X VATZ, VBTZ, AB, AC, BB, BC,

Dimension VATZ(251,14), VBTZ(251,14),  
AB(14), AC(14), BB(14), BC(14)

Also for extra input card write output Tape 15, 904  
2442

2441 IF(IFVE) 245, 245, 2442

2443 write output Tape 15, 936

936 Format (9X, 3H VEF, 7X, 3H PDF, 6X, 4H,  
SHCF, 6X, 6H RHOSOM, 4X, 6H RHOGLM, 1)

2444 Read input Tape 1, 956, 6X, 4H CORE  
x 956, NG, VEF, PDF, SHCF, RHOSOM, RHOGLM,

956 Format (I1, 4X, 6F10.5) CORE

2445 Write output Tape 15,

x 956

replace CORE on card 3 with RSOK

Set RASO = RACT \* RSOK

This will permit  
different soma  
threshold

Handwritten notes at the top of the page, including a date "1/20/04" and some illegible text.

ROUTING WORKSHEET (NT, NS, KE, NG, 2H, 2H, 2H, 2H, 2H, 2H)  
X - KAE, FEVE, FFPIVE, FPAB, CORE  
X - VEF, PDF, SHCF, RHOSM, RHOIM  
X - VATF, VBTZ, AB, AC, BB, BC

Dimensions  
AB(4), AC(4), BB(4), BC(4)  
VATF(221, 14), VBTZ(221, 14)

Handwritten notes in the middle section, possibly a title or description.

2H1 IF(IEVE) 2H2, 2H3, 2H4

2H5 with output tape 12, 2H6

2H7 format (IX, 3HVEF, IX, 3HPDF, IX, 4H)

SHCF, BX, 2H RHOSM, NX, 2H RHOIM

2H8 (with output tape 1, 2H9)

X 2H5, AC, VEF, PDF, SHCF, RHOSM, RHOIM

2H5 format (II, IX, 2H10.2)

2H4 with output tape 12

X 2H5

Handwritten notes in a red circle at the bottom left.

Handwritten notes at the bottom of the page, including the equation  $2H \text{ RAO} = \text{RAC} \times \text{RKC}$ .



9/22/64

~~kinetics with active case gone too much  
much of paper, otherwise good.~~

64794.8854 was pretty good active with hot K,  
dendritic spike nearly synch,  
slight electronic reflection

might increase some I.C. to .3

eg. .3, .25, .20, .10

64794.8855 got too much pos. off. #

\* got neg E (ie. neg B)

in main prog  
from active R.K. sub.

also get this was Parve RK

Also cooler kinetics do this

fix subroutines to prevent B going neg.

~~See previous page~~

in 93C 494C

465 IF (B(JZ)) 4651, 4661, 4661  
4651 DB = - B(JZ) / DELT  
4652 GO TO 467

This should  
eliminate  
neg B

Probably can manipulate heat with RBFR  
 threshold with RBSQ  
 for any given value of RACT

See also p. 58 of Book 4 & p. 35 of Book 4

	Hot	Cool
Ract	600.	400.
RBSQ	1.	1.
RBFR	80.	80.
QA	30.	20.
Root B	50.	50.
Root C	10.	10.
QB	30.	20.
APPOS	.1	.1

		#5 of p. 49 Bk 4	#1	#7
$k_1 = RACT * RBSQ$	600.	400.	500.	500.
$k_2 = RACT * RBFR$	$48 \times 10^3$	$32 \times 10^3$	$4 \times 10^4$	$4 \times 10^4$
$k_3 = ROOT B$	50.	50.	20.	50.
$k_4 = QB / QA$	1.	1.	2.7	2.
$k_5 = QA / RACT$	.05	.05	.03	.05
$k_6 = ROOT C$	10.	10.	5.	10.

$\frac{k_6}{k_3 k_5} \approx \frac{Ess}{g_{ss}}$  for small  $\left( \frac{RACT}{QA} \right) \left( \frac{ROOT C}{ROOT B} \right)$       4      4      ~8      4

$\frac{k_6}{k_4 k_5} \approx \frac{Ess}{g_{change}}$   $\left( \frac{RACT}{QB} \right) \left( \frac{ROOT C}{ROOT B} \right)$       200      200      200      ~60      100

$\frac{k_2 k_5}{k_6} \approx g_{ss}$  for  $V=1$   $\frac{RBFR * QA}{ROOT C}$       240      160      200      240      200

9/23/64 Review kinetic constants while waiting for recompile of new programs.

New 93C + 94C compiled OK.

But 795C + 95C had small errors

Now also necessary to recompile 794C to make compatible with 93C + 94C

Page 90 of Book 4 :

	Hot	Cool	Hot	Med.	Cool
RACT	600.	400.	600.	500.	400.
RBSQ	1.	1.	1.	1.	1.
RBFER	80.	80.	100.	80.	75.
QA	25.	20.	30. 20.	25.	20.
ROUTB	40.	50. → 35. 40.	40.	40.	40.
ROUTC	10.	10.	7.5	7.5	7.5
QB	25. <i>increase</i>	20.	60.	50.	40.
AFPOS	.1	.1	.1	.1	.1

e.g. 8841

e.g. 8741

$k_1$	600.	400.	600.	500.	400.
$k_2$	$48 \times 10^3$	$32 \times 10^3$	$6 \times 10^4$	$4 \times 10^4$	$3 \times 10^4$
$k_3$	40.	35.	40.	40.	40.
$k_4$	1.	1.	2. - 3.	2.	2.
$k_5$	.0416	.0875	.05 .033	.05	.05
$k_6$	10.	10.	7.5	7.5	7.5

Note that QB could be doubled.

ROUTC can be reduced  
 & ~~fit~~ fit the earlier good  
 combinations,

for longer refraat period  
 use ROUTC = 5.

11  
 Now also movement to recognize TPC to make computer  
 Now PSC + PSC computer OK  
 Now PSC + PSC but small error  
 Now PSC + PSC computer OK  
 Now PSC + PSC computer OK

Page 22 of 2000

Code	HT	HT	HT	HT	HT
PACT	600.	400.	400.	400.	400.
R320	1.	1.	1.	1.	1.
RBER	80.	80.	80.	80.	80.
QA	52.	20.	20.	20.	20.
QAB	40.	20.	20.	20.	20.
QAC	10.	10.	10.	10.	10.
QB	52.	20.	20.	20.	20.
QBA	1.	1.	1.	1.	1.

Extracellular Sequence

- KVE=1 VE with zero shunt conductance
- KVE=2 (with shunt factor but without pot. divider  
this can be skipped by using 0 in the hundreds digit of IFVE)
- KVE=3 Includes effect of conical resistance
- KVE=4 Superimposes potential divider effect.

IFVE = 2222 means compute, tabulate + plot all four stages  
 = 1001 means compute and tabulate only 1st + last stage

Could increase VEF

9/28/64 Review The new runs.

64795.9001 & 2 & 3 revealed trouble in Subroutine Argument

64795.9004 Successful with hot kinetics & active dendrites, NSD=5  
5 But trouble with XNSD in Subroutine WXR95C

soma peak at KT=23	periph peak KT=24
22	23

This showed that  $RSOK=1.2$  made soma spike peak occur only one KT step sooner.

In both cases the dendritic spike was nearly synchronous

These are without BEB

	soma	dendritic				
I.C. =	.25	.2	.15	.1	.05	
kinetic counts.	600.	1.	100.	25.	40.	7.5, 50., 0.1

64795.9006 first completely successful full extracellular run (9/25/64)

same kinetics as above, but with I.C. = .3, .25, .2, .1, 0, 0

soma peak at KT=17	periph peak KT=19
-----------------------	----------------------

The extracellulars are acceptable, but neg peak amplitude = -1.2  
pos peaks 0.8

KT=22 The time of the surface neg. does coincide with inflection point of the intracellular spike at soma, rather than peak of periph intracellular

rel. to Jose's question

This fits the time derivative interp. of the differencing between two electrodes.



9/28/64

64795.9007  
(9/25/64)

same as .9006 except that  
RSOK = 1.5

some peaks  
KT = 15

periph peaks  
KT = 17

compared with 17 & 19

also shipping shunt current & cone resistance worked.

Then, on 9/25/64 setup 64795.9008, 9, 10, 11  
and 64794.8855

→ to get active & passive with NSD = 5 & 10

Important Changes: Reduced ROUTC to 5.

Also made "cooler" kinetics for 10 & 11 active

	with	400.	1.	75.	20.	40.	5.	40.	.1	cool
whereas hot	600.	1.	100.	25.	40.	5.	50.	.1		hot

But noticed that so-called cooler kinetics did not propagate more slowly

i.e. took longer for spike to reach peak in first axonal segment, but then prop. as well

perhaps because larger area of spike provides better feeding of next cpt.

cpt 9  
KT=31  
ampl. 475

~~1 bar, or dist. out of / 24752.2008, 9.10, 11  
and 24754.2882~~

29  
474

~~to get into procedure with NAD = 2410~~

~~Important Changes: Reduced KOUTC to 5.~~

~~Also made cooler "binetics" for 10411 active~~

~~But noticed that no call with binetics did not propagate~~

~~i.e. took longer for sites to reach peak  
in first several segments, but  
then pass, as well!~~

~~perhaps because lower one of sites processes  
better feeding of input.~~

K = 12, 14, 17, 39  
.915, .918, .865, .927

Looks as though it would reflect



9/28/64

14

64795.9008

passive dendrites  
fast kinetics, NJD = 5

peak Cpts.	1	2	3	4
KT	6	9	12	23
ampl	.941	.942	.930	.787

This run is good enough  
for a complete run. <sup>NT=81</sup>  
(See p.)

However, can also explore with <sup>(a)</sup> ~~more~~ less I.C. + E

~~perhaps~~ perhaps flat 0.1 for some  $\theta$  & d  
+ B = 0.05 for " " "

.9021

KT	6	9	11	22
Ampl	.942	.945	.930	.794

negligible difference.

(a) Could double RBSQ

(b) another with B = 0.1

(c) another without stimulus  
to check background.

64795.9009

same with NJD = 10

KT = 6, 10, 13, 24 got too much soma delay  
.934, .934, .916, ?

needs more compl

6, 9, 12, 41

try above. RBSQ = 2

64795.9010

active dendrites with cool kinetics  
NJD = 5

got synchronous dendritic  
spike

KT = 10, 13, 16, 32 & perhaps 32  
.909, .909, .857, .939 .951

← 64795.9011 ~~same~~ same with NJD = 10  
soma delay too long.

PHAS. 9008

Redo 22, 23 & 24 with  $NT=51$  altogether

However, can also appear with two L.C. + 3

↑  $B = 0.02$  for " " " "

- (A) another with  $B=0.01$
- (B) another without structure
- (C) to check back ground

PHAS. 9007 same with  $NTD=10$

get too much some delay  
 needs more samples  
 together  $NT=51$

PHAS. 9010 entire bundle with cut limiter

cut limiter with  $NTD=2$   
 $T = 10, 13, 16, 25$   $\Delta t = 35$   
 $NT = 10, 13, 16, 25$   $\Delta t = 35$

9/28/64

setup 64795.9015 <sup>passive</sup> same as .9008 with IFTEST=0

Time Est.

~~225~~ ~ 300 } 313

IFVE = 2012  
NPLT = 3  
NG = 2  
NT = 81

116 ~~150~~ 140 } 64795.9021 NT=61 RBSQ=2. IFVE=1000  
OK but negligible difference IFTEST=1103111

116 ~~150~~ 140 } .9022 RBSQ=1, but NES=1 & B=.05 in S&D  
lost BEB ∴ blocked I.C. = .1 in S&D

117 ~~150~~ 140 } .9023 " " same with B=.1 in S&D

did not run because of error } 130 } .9024 Same as .9023 without I.C. in axon.  
as a control.

above all for NSD=5  
following for NSD=10

Actual } 176 200 } .9025 NT=81, RBSQ=2., I.C. as in .9009

200 } .9026 RBSQ=1, NES=1 & B=.05 in S&D  
I.C. = .1 in S&D

200 } .9027 same except B=.1 in S&D.

200 } .9028 control with zero I.C. in axon

active } 240 } .9029 similar to .9011 but with  
NT=81, NES=1, B=.05, .04, .03, .02, .01

production  
60/1040  
17

70 pages

setup BHP2.P012 same as P008 with TEST=0  
 FEVE = 2112  
 NPT = 3  
 NG = 2  
 NT = 81

313

PT 212.P001 NT=61  
 FEVE = 1060  
 TEST = 110311  
 R220 = 2  
 R220 = 1  
 NET = 1  
 B = .02 in 24D  
 IC = .1 in 24D  
 P023  
 P024 same as P023 with I.C. in open case control

140  
 140  
 140  
 120

show all for N2D = 2  
 following for N2D = 10

P022 NT=81, R220 = 2, I.C. as in P008  
 P026 R220=1, NET=1, B = .02 in 24D, IC = .1 in 24D  
 P027 same as P026  
 P028 control with I.C. in open

200  
 200  
 200

P029 similar to P011 but with NT=81, NET=1, B = .02, IC = .03, OS

240  
 240  
 17

9/30/64

16

Problem 64795.9015 revealed error at statement 691 of WXR95C which affects only the CONE calc for persone dividends & was not previously tested. This now being fixed together with minor change at 743 to be explicit about skipping shift factor whenever shipped. This error discovery justifies the caution in setting up .9015 as less than a full run, (as originally intended).

We can now judge if  $NT=81$  is too much.

perhaps not.

64795.9021 RBSQ = 2. made very little difference  
one KT earlier in yts. 3 & 4  
∴ Might even try RBSQ = 5.

.9022-24 blocked because BEB input card was incorrect  
similar trouble with .9026-28

need resun

Run time →  
estimated at 100secs  
was 100secs

... to some extent ...  
... about 100secs ...  
... was not ...  
... this was ...  
... at 50% ...  
... together with ...  
... be expected about ...  
... This was ...  
... in ...  
... (approximately ...)

... in 18=11 ...

... RBSQ = 2 ...  
... one KT ...  
... RBSQ = 5 ...

... BFB ...  
... 28-28 ...  
... been

Principal difference is that both B+C grow faster with  
RBSQ=5. & hence reach peak conditions sooner  
in opt. 4. Difference presumably not enough in opt. 3  
because safety factor is greater. The actual peak values  
in opt. 4 (at different KT) are very similar.

10/1/64 (set up 9/30/64)

17

64795.9031 RBSQ=5. otherwise like .9021 + .9008

Here peaks in cpts

	1	2	3	4	9
KT	6	9	11	19	26
	.942	.945	.938	.807	.468

soma spike is earlier, cf. p. 14, whereas cpts 1, 2 & 3 are same  
3 very slight.

64795.9032 and .9033 SNAFU because neglected to set NET=1

It is very interesting that increasing RBSQ from 1. to 5. had no essential effect upon axonal propagation, but significant effect upon soma delay. Now look at B+C values

.9021

.9031

KT=11	opt 3	opt 4	KT=11	opt 3	opt 4
	.9301	.3328		.9375	.3801
	.7005	.0207		.8927	.0374
	.3499	.0225		.6509	.0384

KT=15	.5991	.4582	KT=15	.4851	.5969
	.1741	.0655		.0933	.1619
	.7301	.0794		.9099	.1702

KT=22

.7941  
.4572  
1.0257

KT=19

.8071  
.5080  
1.0258

Estimated Runtime		Actual
.9016	380	390
.9035	380	346
.9036	180	163
.9037	180	163
.9039	380	418

1500 secs  
on 25 min -

Actual runtime was 1485 secs

on 25 min



better not put  
BEB in soma



10/1/64 (set up 9/30/64 production run)

64795.9016

Intracellular is fine.

SNAFU with CORE

Could it be that they did not have the new version of 95C incorporated into their production run?

64795.9035

RBSQ = 5. pressure NSD = 10 compare with .9025

	.9025				.9035			
Cpts.	1	2	3	4	1	2	3	4
KT	6	9	12	41	6	9	12	30
	.937	.936	.918	.756	.940	.942	.923	.7786
eff. 14	KT = 56, ampl. = .270				KT = 45, ampl. = .274			

prefer RBSQ = 5.

~~still~~ Here also trouble with 95C CORE

64795.9036 blocked, but might have been OK. with RBSQ = 5.

64795.9037 **good** with BEB = 0.1 did not block  
Some peaks @ KT = 30, ampl. = .6765

eff. 14 @ KT = 48, ampl. = .246

10/11/10 (date of paper production run)

817 393 393

PH 1016

intercellular in fibre

SWAFD with CONE

Call to the firm but not have the

most version of PTC incorporated

see production run

in 25

PH 1035

compare with 1032

in 25

1032

1032

4	3	2	1	3#N	2	1
30	15	9	6	12	9	6
0.178	0.143	0.145	0.140	0.18	0.18	0.171

KT=42, wpl=22.74

KT=20, wpl=23.0

0.0 paper RB20 = 2.0

There are trouble with PTC core

Blocked, but wpl was low

OK with RB20 = 2.0

with RB20 = 0.1 and wpl

several of KT = 30, wpl = 15.62

KT=18, wpl=24

10/1/64

64 795.9039

active with NTD = 10  
cooler kinetics

Note ① Here Cone calc. works!  
presumably because active

② Also BEB was far too effective  
reduce I.C. & maybe make flat  
also, might as well use  $RBSQ = 5$ .

Encouragement to use flat facilitation  
certainly for passive, but  
perhaps even for active.

Some surface area approx 120 of side 20  $\mu$  m  
get  $6 \times 20^2 = 2400 \mu^2$

So when NTD = 10,  $\frac{C_0}{C_s} \approx \frac{1}{10}$  so here  $\frac{USA}{VA}$  similar to

When NTD = 5,  $\frac{C_0}{C_s} = \frac{1}{5}$  USA similar to

Really, however  $\frac{USA}{VA} = \frac{1}{5} = \frac{1}{5}$

active with  $KTD = 10$   
cost function

64 742, 0039

Note ① How does calc. work?  
probably become active

② Also BEB was too effective

reduce I.C. through water flat  
also, maybe overall use less

management to use flat for activities  
certainly for personal use  
perhaps even for active

10/1/64

Comparing N/D = 5 & 10

True distance from soma to glom  $\approx 0.4$  mm.

When N/D = 5, compartmental  $\Delta X = 0.08$  mm  
 $= 80 \mu$

When N/D = 10, compartmental  $\Delta X = 40 \mu$

We have been assuming that  $\Delta X$  is same for axon & dendrites  
and thus  $\frac{UA}{UD} = \frac{\text{axon diam}}{\text{dend. diam.}}$

If  $\Delta X = 40 \mu$  and axon diam =  $2 \mu$ , surface area of one  
axonal compartment  
is about  $240 \mu^2$

If  $\Delta X = 80 \mu$  ————— get  $480 \mu^2$

Soma surface area approx that of cube  $20 \mu$  on side  
get  $6 \times 20^2 = 2400 \mu^2$

When N/D = 10,  $\frac{CA}{CS} \approx \frac{1}{10}$   $\therefore$  here  $\frac{USA}{UA}$  should be  $\frac{1}{10}$

When N/D = 5,  $\frac{CA}{CS} = \frac{1}{5}$   $\frac{USA}{UA}$  should be  $\frac{1}{5}$

Recently, have used  $\frac{USA}{UA} = \frac{5}{25} = \frac{1}{5}$  but should use  
 $USA = 2.5$   
 $USD = 100$   
for a ratio of 40

10/1/04

Comparing NTD = 2 & 10

Two distance from source to plane x 0.1 mm

80.0 = XA  $\Delta X = 0.08$  mm  
 % error NTD = 2,  $\Delta X = 0.08$  mm  
 = 80%

Where NTD = 10,  $\Delta X = 0.08$  mm  
 = 8%

We have been assuming that  $\Delta X$  is same for error of distance  
 and thus  $\frac{VA}{VD} = \frac{error}{error}$

if  $\Delta X = 40\mu$  and error here = 40%  
 and error here = 40%  
 in about 240%

Whereas for  $VA = 25$  have  $\frac{USD}{USA} = 40$

	VA	VD	USA	USD
NTD = 5	25.	100.	5.	200.

	VA	VD	USA	USD
NTD = 10	25.	100.	2.5	100.

Generally, we want  $\frac{VA}{VD} = \frac{2}{2} = 1$

10/1/64

21

Conclusions, might wish to try

$$\frac{VA}{VD} = \frac{1}{3} \quad \text{eg. } \frac{33}{100}$$

look back at page 70 of Book 4  $\frac{USD}{USA}$

Consider minimum dendrites as 1 primary & 2 sec.  
with diameters approx 3 times axons.

$$\text{then } \frac{USD}{USA} = 3 \times (3)^2 = 27.$$

Consider one primary with diam ratio = 4  
3 Sec.

$$\begin{array}{r} 2 \times 4 \\ 16 + 3(2)^2 = 28 \\ 16 + 4(2)^2 = 32 \end{array}$$

---

all runs have  $VD = 100$

we could do some runs with  $VA = 33$

$$\frac{USD}{USA} = 2.5$$

	VA	VD	USA	USD
for $NJD = 5$ this means	35.	100.	7.	175.
for $NJD = 10$	35.	100.	3.5	88.

12

10/11/03

# Computer Time on Production Run

	Rough Est.	Actual	Cum
9041	118	110	
9042	118	111	221
9043	112	104	325
9044	120	116	441
9045	200	219	660
9046	100	114	774
8046	100	113	887
9047	100	109	996
8048	<u>263</u> added	<del>277</del>	<del>1273</del>
9048	263	278	1551
9049	263	277	1828
	<u>1757</u>	<u>1828</u>	



These all need fail removed from some

10/2/64

Quick overview of new results.

64795.9041

flat residual fail worked fine.

? preferable to 9031 (where some spike onset is more gradual)

some peak = 81

Passive with  $NJD = 5$ , with no E

Also come now working, evidently previous series had not used the new 95C

Good extracellular series - suitable for plot.

64795.9042

flat residual fail 0.1 plus  $B = .05$

hitoc peak at  $KT = 11$  } longish delay.  
sound 11  $KT = 35$  }

some peak 75

possible for use: did not reflect.  
but next case is probably better.

64795.9043

same as done with  $B = .1$

good run.

But may need controls to see if 41 & 43 would fire without antidromic.

Ideal may lie between 42 & 43

Noxtrum could be like 43 without E in some

do check out for this

afraid that these would fire without antidromic

Compute the... (faint text)

10/2/01

9041 flat residual fact worked fine  
9042  
9043  
9044  
9045  
9046  
9047  
9048  
9049  
9050  
9051  
9052  
9053  
9054  
9055  
9056  
9057  
9058  
9059  
9060

Also case was working, but not using the new PSC series but not used the new PSC series

Good extracellular series - started for plots?

9042 flat residual fact 0.02  
9043  
9044  
9045  
9046  
9047  
9048  
9049  
9050  
9051  
9052  
9053  
9054  
9055  
9056  
9057  
9058  
9059  
9060

proportion for use: but not reflect. but not case in probability.

9043 same as above with B = 01

good in

But may need controls to see if P1 & 2 would fit without outbursts.

Abol may lie between 42 & 43

These would fit with outbursts

Minimum could be like P3 with 2 in series

10/2/64

64795.9044 active, "cool", short flat mild facilitation  
(both residual & B)

got synchronous somadendritic  
with "good" axon-soma delay.

Extracellular is like  $\frac{dV}{dt}$  & amplitude is only 0.2 mV.  
for VEF = 4.

down a factor of about 10 from non-  
synchronous dendritic spike.

of interest for Stefanis story

We cannot rule out VEF = 40. a priori, but  
it can probably be ruled out on the basis that  
E & J can modify invasion such that  
synchrony would not always obtain. ?

Any variation in synchrony would  
have severe effect on amplitude.

Also, delay of of neg peaks with distance  
may be diagnostic etc. - should be checked.

10/2/01

64525.0044 active, cool, sweat that with facial motor (with ventral 4B)

got synchronous some amblyopia with "good" or even some delay.

Optic chiasm in line of  $\frac{1}{2}$  amplitude in only 0.2 mm. for VEF = 4.

down a bit of about 10 from now - synchronous amblyopia.

Optic chiasm 2 days

We count only one VEF = 40. superior, but it can probably be ruled out on the basis that 2 of 3 can make minor error such that synchronous words, not always obvious. Our restriction in synchronous words have severe effect on amplitude.

Also delay of responses with distance may be diagnostic. - standard checked.

10/2/64

24

64795.9045 pasore NJD=10

USA=2.5 USD=100.

flat residual facil! = .25 in dendrites  
but not soma

Soma fired at KT=18

good run

it is clear that residual facil was decaying  
& would not ~~likely~~ fire without antidromic  
See p. 32

amplitude decrements to 0.25 in opt. 14

Should plot

excellent, but  
check control without antidromic.

~~pos filter~~  
pos peak of period II of soma  
is very slow,  $\text{ampl} \approx \frac{1}{4}$   
of neg peak  
in Period I

64795.9046 pasore as above

but with  $B = .05$  in dendrites

I.C = .1 in soma & dendrites

Soma fired at KT=43

64795.8046 same as 9046 except that USD=62.5

here soma fires at KT=27

64.795.9047 like .9046 except  $B=0.1$  in dendrites

here soma fired at KT=39

X

must not be too sharp

The problem of minimum amplitude proximal to glomerulus may be resolved or avoided by the primary & secondary streaming which will make periphery necessarily have lower amplitude.

A contra-indication for the active synchronous case is the very small <sup>peak</sup> amplitude at intermediate depths.

Consequences of synchrony

- ① small amplitude of extracellular
- ② faster fall of intracellular
- ③ more nearly equal size of  $+$  &  $-$  peaks  
(as expected for  $d \neq 0$ )
- ④ get ~~the~~ minimal amplitude at intermediate depths.

?

Must discover basic cause of dip, because it may occur also with passive (it is a cancellation due to PD effect)  
? phase

10/2/64

Active with  $N/D = 10$   
"cool" kinetics

flat facilitation

64995.8048

USD = 62.5

I.C. = 0.1 S &amp; D

B = .01 in D only

Soma fires at  $KT = 24$ 

cpt. 14

25

nearly synchronous

expect  $\frac{dV}{dt}$  approx for  $V_e$  $KT = 22$   
ampl = -.54  
for  $VEF = 4.$ 

Might pay to try to slow falling phase.  
Because falling phase is not counteracted by electrotonic  
back flow from a later downstream spike,  
since here spike is synchronous.

64795.9048

same as 8048 with USD = 100.

almost synchronous

Soma fires at  $KT = 24$ cpt. 14 at  $KT = 25$ 

trivially different from .8048

64795.9049 had I.C. flat, but B values graded  
(similar to .9039) but better

Here dendritic invasion is progressive

Presumably soma would fire without the  
antidromic. This needs to have  $E$  taken out of soma

10/2/04

Active with WTD = 10

flat for station

"cool" binding

PPPs: 8048

USD = 85.2

I.C. = 0.1

2 & D

B = .01 in D only

Some part of KI = 24

off. 14

mainly symmetrical

expect the effect for the

only = .24

POWER = H.

beginning of the...  
thought for a...  
beginning of the...  
book flow from a...  
since there are...

WTD = 100  
USD = 100

the effect...  
KI = 24  
KI = 28

two different forms, 8048

PPPs: 8048 - WTD = 10, flat for B...  
(similar to 10031) but better

How the... in progress

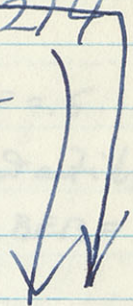
Program... some would fire without the...  
out... This needs to be...



10/2/64

26

Could do a sequel to ~~64794.8214~~  
for granule cell with  
RHO SOM = 1.0  
RHO GLM = 1.6



Use  $VEF = \frac{10.}{5.}$

See 8215

9/15/64

DT = .01

RSOK = 1.0

8216

NSTEP = 5

needs card 6

9/16/64

NT = 70

~~could be a sequel to 4/10/04~~  
 for example cell water  
 $\rho_{H_2O} = 1.0$   
 $\rho_{H_2O} = 1.0$

see 8/12/04  
 2/12/04

$\text{we } VEF = \frac{10}{2}$

$R_{20K} = 1.0$   
 needs only

$DT = 0.1$   
 $WATER = 2$   
 $NT = 50$

10/5/64

Set up production run

	est. time	
<del>47</del> 795.9051	116	I.C. = 0.2, PDF = .5
52	90	control without antidromic
53	116	I.C. = 0.1 with BEB = .1
54	90	control
55	90	control on 45
My wish to increase I.C. to 0.25		
57	260	same as 58 with BJC for decrement
58	260	same as 48 with QB reduced
59	277	" " 49 with some BEB deleted
	<u>1299</u>	

.8217 300

.8218 300

x	1900
60	

31.3

4795.9052 control with I.C. = 0 in opt. (1)

Actual run time was 1994 secs

- ① We may have to tolerate a low level of jitter in firing. However, exp. less than 10% per sec.
- ② RBSQ may have to be set back from 5<sub>1</sub> to 1<sub>1</sub>, but this may require more surgical work, to prevent antidromic block.
- ③ Perhaps initial condition needs to include some refactory BJC in the appnd + some opt.

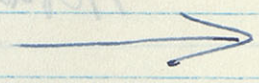
2nd up production run

Control without substrate	90	75
Control with substrate	90	75
Control on H2	90	75

same as 28 with 82C substrate	90	75
same as 28 with 98 substrate	90	75
" " " " " "	90	75

1500  
 300  
 300  
 2100  
 2100  
 2100

note that extracellular pots. are essentially the same for this as for antidromic



Actual run time was 144 sec

10/6/64

Looking over results of production run

28

64795.9051 Passone, NJD=5, hot, I.C. = 0.2 flat in dendrites  
but not soma, ~~NEJ~~ NEJ=0

Some peak occurs at  $KT=32$   
(in .9041 " " " "  $KT=16$ , but <sup>probably would</sup> might have fired  
without the antidromic.

May wish to increase I.C. to 0.25

intracellular  
peak amplitudes  $\mu V$

4	5	6	7	8	9
.77	.64	.55	.49	.47	.46

The extracellular pots. are not pretty enough; maybe  
this reaction is mainly to the delay, but period II  
is rather blunted.

64795.9052 control with I.C. = 0 in  $\mu V$  (1).

soma fired at  $KT=38$   
hillock fired at  $KT=27$

- ① We may have to tolerate a low level of spontaneous firing. However, exp less than 10 per sec.
- ② RBSQ may have to be set back from 5. to 1., but this may require more residual facil. to prevent antidromic block.
- ③ Perhaps initial condition needs to include some refractory BTC in the axonal & soma  $\mu V$ .

04795.9021 Pressure,  $NTD=2$ , but,  $I.C.=0.2$  flat in double but not some,  $NET=0$

Some peaks occur at  $KT=32$   
in 9041 " " " " " "  $KT=16$ , but might have field  
without the outburst

Work to increase I.C. to 0.25

Peak outbursts at .4 .5 .6 .7 .8 .9  
75. 74. 73. 72. 71. 70.

The extracellular part, are not pretty enough; maybe  
this section is meant to be delay, but phase II  
is rather limited.

04795.9022 control with I.C. = 0 in pt. 10

some fixed at  $KT=38$   
note that interval  $NTD \approx T$  to be fixed  
essentially the same for this

1) The way has to tolerate a large block of outbursts  
during. However, esp. low for 10 for see.

2) RBD may have to be set back from 2. to 1, but  
this may require more residual fuel. to prevent  
anti-dramatic blocks.

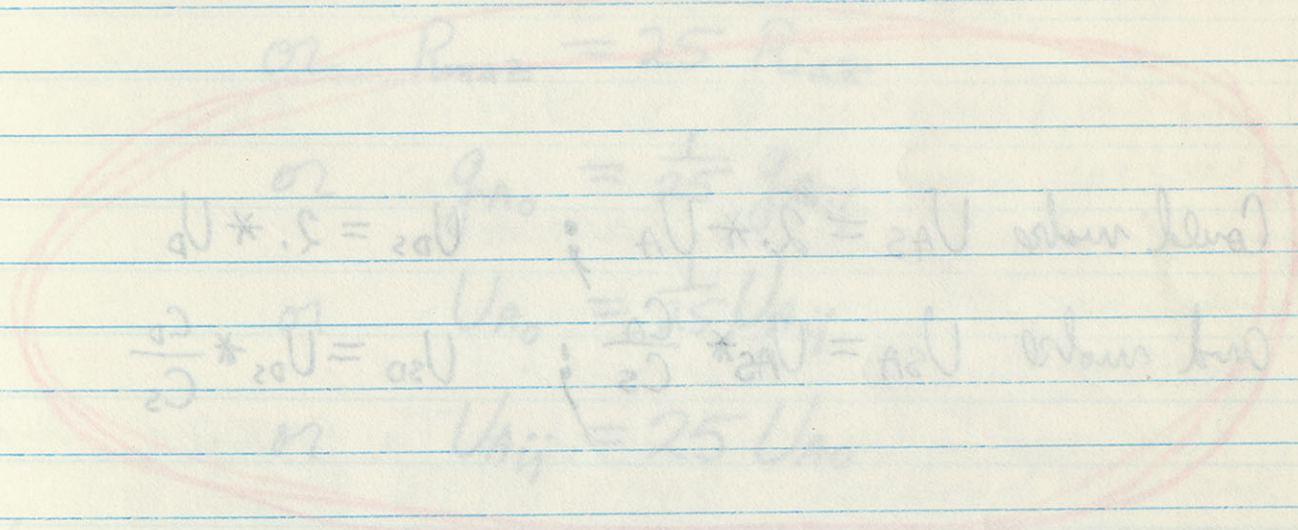
3) Perhaps initial condition needs to include some repeating  
BTC in the open & some etc.

10/6/64

~~29~~ 29

One implication is that, with passive dendrites, a soma spike does have significant electrotonic spread into the dendrites, but the dendrites do not actively "clear" themselves, & residual facil. is temporarily enhanced (which may not fit physiological facts? i.e. dendrites are facil. (depol.) but are the soma & hillock refractory?)

Important to follow the recovery of soma and hillock BEB + BSC after firing to see how refractory & also to see how much soma repolarization does to clear the dendrites?



Now, measure  $g_m = g_{Na} + g_{K} + g_{leak}$

Intuitive explanation of why spike starts at the soma & electrotonic spread from the hillock. The hillock is the site of the soma to dendrite junction, where the area of soma is small compared to the area of the dendrites, so the resistance is high, and the capacitance is low, so the time constant is short, and the spike starts at the hillock.

64795.9054

Control got local resp leading to  
peaks at  $KT=42$  in Cpts 1+2  
 $KT=44$  in Cpt. 3  
 ~~$KT=48$~~

~~which~~

Cpt. 3 got ahead of Cpt. 4 at  $KT=25$

$$\text{Could make } V_{AS} = 2. * U_A ; \quad U_{DS} = 2. * U_D$$

$$\text{and make } U_{SA} = V_{AS} * \frac{C_A}{C_S} ; \quad U_{SD} = U_{DS} * \frac{C_D}{C_S}$$



10/6/64

64795.9053 ~~\*~~ passive,  $NSD=5$ , hot,  $IC=.1$  s+d  
 $BEB=.1$  in D only.

Control 54

soma blocked  
 peak was .1702  $\sigma$   $KT=15+16$

previously 42+43 had BEB  
 in the soma & did not block  
 but <sup>suspect</sup> would have fired without antidromic

notice  $\frac{USA}{VA} = \frac{5}{25}$

$VSS = 206$ .

Note that  $VA=25$ . means that  $\Delta Z = \frac{1}{5}$

$\therefore R_{i\Delta Z} = \frac{1}{5} (r_{id})$  while  $R_{m\Delta Z} = 5 \left( \frac{r_m}{a} \right)$

or  $R_{m\Delta Z} = 25 R_{i\Delta Z}$

or  $g_{A0} = \frac{1}{25} g_{Aij}$

or  $U_{A0} = \frac{1}{25} U_{Aij}$

or  $U_{Aij} = 25 U_{A0}$

Now, we assume  $g_{SA} = g_{AS} = g_{Aij}$

Intuitive explanation of soma block is that the rate of electrotonic spread into the dendrites is rapid.

Therefore depolarizing current from hillock must block the loss of soma to rapid equalization tendency. As  $USD$  and  $UD$  are increased to larger values, the soma capacity is

Compare 64794.8853 & 4 (9/22/64)

where USA=10. & USD=400.

gave longer axon-soma delay

than USA=5, & USD=200.

~~everything else the same~~

However these dendrites were active,

may need to be rechecked with passive dendrites

in this case, the key to the difference is that the soma had a large I.C. and lost it less rapidly (because of layer C, smaller USA & USD) than in the 53 of this setup an earlier soma local response & earlier soma firing in spite of weaker feed from luteoc.

10/6/64

31

placed more & more instantaneously in parallel with the dendritic capacities & it becomes less & less responsive to depolarizing current. Also any brief excess of soma depol over dendritic depol. disappears very rapidly.

Also, the amount of current flowing into the soma as a consequence of hillock spike is proportional to USA.

∴ Doubling USA doubles current into soma.  
but Doubling USD doubles tendency of soma to equalize with the dendrites.  
The net result is less sensitive soma response.

Note: p. 24 64795.8046, decreasing USD only, caused soma to fire sooner for case of passive dendrites. Because exchange rate with dendritic load was reduced, i.e. soma was less sluggish,

but, p. 25 64795.8048, decreased USD had very little effect when dendrites were active.

had more + more instantaneous in parallel with  
 the dendritic capacitor + it becomes less +  
 less response to depolarizing current. Also  
 my brief period of some delay over dendritic  
 delay. Disappears very rapidly.

Also, the amount of current flows into the  
 soma as a consequence of Wilbur's factor  
 is proportional to  $USA$ .

$1/2$  of the USA banks remaining in soma.  
 but  $1/2$  of the USA banks remaining in soma to  
 $0.01 = 0.01$  = 100% = 100%  
 yet the amount in the soma is very small

Note:  $0.125$  of  $0.125$ ,  $0.125$  of  $0.125$  only  
 cannot come to the soma for case of  
~~response to dendritic~~ because exchange  
 rate with dendritic load was reduced.  
~~input's soma was also reduced.~~  
 it is back in the soma dendritic  
 but  $0.125$  of  $0.125$ ,  $0.125$  of  $0.125$  had  
 very little effect when dendritic load  
 was reduced.

the difference is that the soma  
 is not as fast as the dendritic  
 (USA/USA) then in the  
 case of a small soma response & early  
 after the input of the dendritic

10/6/64

64795.9054 - Control for 53

(see p. 30 & opposite.)

This shows that it is possible to have spontaneous firing of hillock & axon without firing of the soma. The soma just sees depol. up to 0.2

~~Impulse arises at cpts 1+2, say at first node.~~

64795.9055 Passive, NJD=10

Control for 9045 without antidromic

~~Soma fired at KT=~~

peaks	Cpts. 1	2	3	4
KT =	13	14	16	19

whereas for

9045	6	9	11	18
------	---	---	----	----

64795.9057 active NJD=10

attempt at decremental story

blocked at soma.

BJC = .1, .2, . . . . . 1.0  
 cpts 5 6 . . . . . 14

Control for 23 - Control for 23  
(see p. 30)

The change that it is possible to have  
of either of the two  
The same first case before.  
up to 0.2

Control for 2042  
Remove NAD=10

~~Control for 2042~~  
KT = 13  
KT = 14  
KT = 16  
KT = 19

Control for 2042

Control for 2057  
Remove NAD=10  
Control for 2057

Control for 2057  
Remove NAD=10  
Control for 2057

10/6/64

QB=30,

33

64795.9058 active, NTD=10, cool kinetics

I.C. = 0.1 in S & D

BEB = 0.01 " " " "

Compare with 9048 where QB=40.  
(p.25)

same synchronous spike at KT=24, 25  
very small extracell.

64795.9059 active, NTD=10, cool kinetics

QB=40.

~~shaped I.C. to~~

flat residual fail  
shaped BEB same as  
9049 except here  
not in soma.

\* pretty good extracellulars

but (a) does special shaping

(b) would fire from shaping alone

would be suitable for plotting, except would  
like fall of intracellular to be slower.

See below get  $\rho_1$  if half of the mitral cells fire:

$$\frac{VEF}{100} = \frac{1}{14} \text{ for } R_e = R_i$$

i.e. .07

$$\text{get } \approx \frac{4}{14} \approx \frac{1}{3.5} \text{ for } R_e = 4 R_i$$

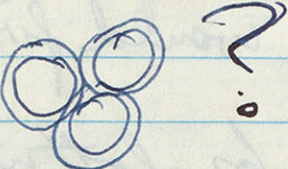
i.e. 0.285

$\approx 0.03$

~~Suited for positive  
dendrites or slow  
axons with significant  
SHUNT current.~~

~~Suited  
for nearly  
synchronous  
dendritic  
spikes~~

~~Suited for  
passive  
axons~~

alternatively could take on  $R_e \approx 50 \Omega \text{ cm}$   
and estimate true extracellular crosssect.  
which however would be something  
like 

note granule cell dendrites & axons which  
lie parallel to mitral dendrites will, if they  
are several  $\lambda$  long, will be open to current  
flow between mb. level & glomerular level.

Thus we might approach  $\frac{R_e}{A_e} / \frac{R_i}{A_i} = \frac{A_i}{A_e} = \frac{100}{800-100} = \frac{1}{7}$   
assuming that all mitral cells fire



10/6/64

34

64795.8217  
.8218

granule cell series.

pretty good runs

get surprisingly sharp reversal  
of extracellular in opt-8

$$\frac{VEF}{100} = \frac{r_e}{r_i} = \frac{R_e/A_e}{R_i/A_i} = \frac{250/800\mu^2}{50/(5 \times 30)\mu^2 \text{ per cell}} = \frac{5 \times 150}{800} = \frac{750}{800} \approx 1$$

1200 mitral cells per  $\text{mm}^2 = 10^6 \mu^2$  $\therefore$  each has  $A_e \approx 800 \mu^2 - A_i$ full crossed.  
Re effectivealternative  $(3 \times 30) = 90$  got  $\approx \frac{1}{2}$ 

~~$A_i \approx 100 \mu^2$~~   
 $A_e \approx 800 - 100 = 700$

$$\therefore \frac{R_e}{R_i} \frac{A_i}{A_e} = 5 \left( \frac{1}{7} \right) = \frac{5}{7}$$

Suppose only every other mitral cell fires, then  $A_e \approx 1600 \mu^2 - A_i$ 

$$\text{then get } 5 \left( \frac{1}{16} \right) \approx \frac{1}{3}$$

Gordon volleys were often slightly less than maximal; however, it is possible that a substantial fraction of the mitral cell population blocks at the soma, perhaps not the same cells on each test. Presumably there is graded dist. of safety factor.

looked at 64795.9058

opt. 10

where neg peak amplitude was  $\approx 0.02$

but some neg peaks are  $\approx 0.41$

would need

$$VEF \approx 5 \times 4 = 20.$$

10/6/64

35

If previous page is correct, we can justify VEP values as large as 10. to 50. which means that the almost synchronous dendritic spikes would have ~~at~~ extracellulars of sufficient amplitude to agree with experiment.

← Must re-examine such cases of active dendrites.

Raised question as to whether facilit can result from ~~volley~~ previous volley (usually 1 sec) earlier.

Inhib. usually lasts  $\approx \frac{1}{2}$  sec but found only in about half the cells

---

Period I seems to require the potential divider works equally well for active + passive effect.

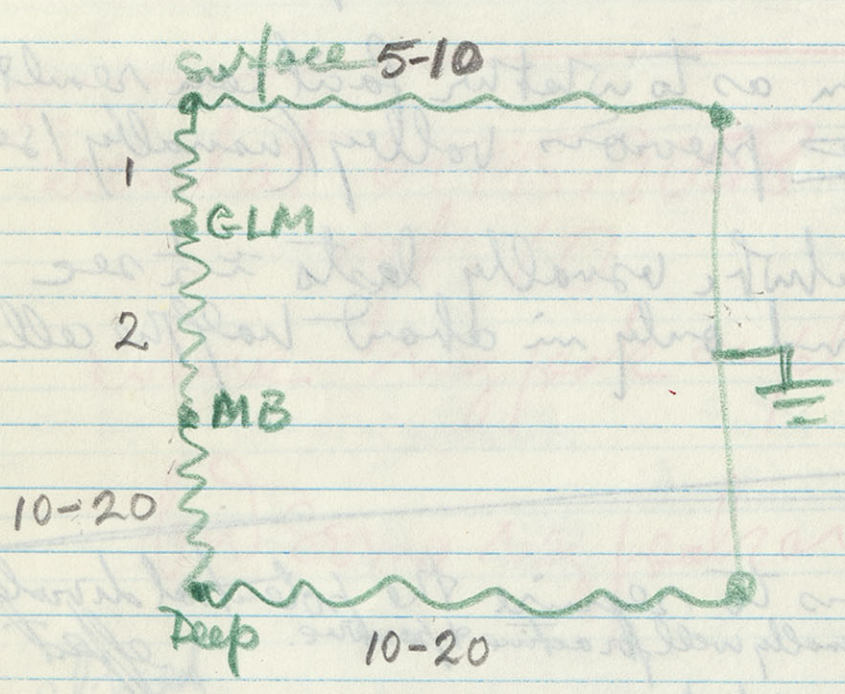
Period II should have a reversal point of rather small neg. if it were due to initial GEC only.

Probably need to use deep axonal GEC to take care of this.

~~However, Period II has a durable~~  
~~However,~~ The intermediate triphasic record has a prominent negativity which is hard to duplicate with initial GEC alone (i.e. with nearly synchronous active dendrites)

of previous page is correct, we can justify VEP values as large as 10 to 20. It means that the almost equivalent conductivities of spheres would have of approximately coefficient equivalent to agree with experiment.

$$SHCF = \frac{2}{25-50} \approx \frac{1}{10} \text{ to } \frac{1}{20}$$



$$\frac{R_{gl-gd}}{R_{MB-gd}} = \frac{6 \text{ to } 11}{20 \text{ to } 40} = \frac{1}{2} \text{ to } \frac{1}{7}$$

see p. 85-87 of book 4

$$\frac{R_{surf-gd}}{R_{mb-gd}} = \frac{5 \text{ to } 10}{(5 \text{ to } 10) + 3} = \frac{5}{8} \text{ to } \frac{10}{13}$$

$$\frac{6}{8} \text{ to } \frac{11}{13} \quad \frac{3}{4} \text{ to } \frac{5}{6} \quad \frac{1}{2} \text{ to } \frac{3}{4}$$

10/6/64

36

Even the passive dendrite case has trouble with the amplitude of negativity in the transitional triphasic.

Here again, need deep axon GEC

This serves two purposes

- ① it shaves surface pos. of Period I to make the peak ~~seem~~ be earlier.
- ② it provides robustness of the transitional triphasic.

10/6/64


Ponder the transitional triphasic

See next page

10/2/64

To mimic deep axon GEC get a soma spike with little or no dendritic invasion, by making UD very small.

From the former dendrite case has trouble with the emphasis of negativity in the transitional tetrophase.

This criticism applies primarily to the synchronous active dendrites. 

In particular, the stepped active .9059, has a very prominent ~~the~~ negative peak in its transitional tetrophase.

Forbes the transition tetrophase see next page

Tommy's deep eye GEC got a some spike with little or none. behavior invariance, very small.

Handwritten notes and diagrams at the bottom of the page, including mathematical expressions like  $R_{total} = \frac{R_1 R_2}{R_1 + R_2}$  and  $R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$ .

10/7/64

What are the discrepancies of using Mitral GEC only.

① Period I surface + peaks a little earlier than deep neg.

~~② Period~~ <sup>theoretical</sup> transitional triphasic has a negativity that is too small (because of PD cancelling effect) <sup>(look in depth + in time)</sup>

rel to surface neg.  
③ <sup>Experimental</sup> Period II surface neg tends to be larger in abs value than the surface pos. of Period I, ~~which~~ while deep pos of Period II is smaller than deep neg of Period I.

Whereas Theoretical, for passive dendrites has a much smaller surface neg. in Period II.  
For active dendrites, depends upon details of  $\frac{dV_i}{dt}$ .

Why are the discrepancies of very little effect only?

① Period I surface + holes a little earlier than deep ref.

(time - association)

② ~~Period I~~ transition with time has a negative effect that is too small (beam of 99 m/s)

(assumed)

③ Period II surface ref tends to be larger in value than the surface ref of Period I

While deep ref of Period II is smaller than deep ref of Period I.

When theoretical, for some holes has a much smaller surface ref. in Period II for some holes, depth of holes of

1/2  
1/2  
1/2



10/7/64

plot best <sup>computations</sup> ~~records~~ now available 38  
64795.

passive NJD=10, probably best is .9045  
cf. ~~\_\_\_\_\_ .8046~~  
no extracellular

active NJD=10, .9058 ~~or~~ .9059  
flat shaped also old <sup>64791</sup> ~~0669~~

short passive NJD=5 .9041 <sup>64791</sup>  
also old ~~0666~~

short active NJD=5  
essentially synchronous .9044

another short active NJD=5 .9006  
some peaks at KT=17, periph peaks at KT=19

10/8/64

.9041 slightly better short passive than .0666

.9069

.9059 and .0669 shaped active long  
These both have the most prominent  
transitional triphasic. They will be  
superseded by .9069 with QB=30.

peak neg.

- 0.22 with VEF=4. • 9044 is best case for synchronous active dendrites
- 0.414 with VEF=4. • 9058 is good for showing problems of || || ||
- 0.78 with VEF=3. • 9006 is O.K. but adds nothing to the other two  
except note amplitude factors here.

.9045 is a good long passive, but <sup>less sharp</sup> slower than .9041

10/7/04

38 plat best ~~was~~ available  
C4102

Pressure NTD=10, probably best in . P042  
of  
no system

10/7/04  
10/7/04

curve NTD=10, P042  
P042  
P042

what pressure NTD=2  
P041  
check

what curve NTD=2  
P044

what curve NTD=2  
P000  
KT=15, KT=15

10/8/04

10/8/04 slightly better start pressure than 0.000

0.000 and 0.000 shaped curve large  
These both have the most prominent  
transitional trough. They will be  
superior to 0.000 with QB=30.

0.000

0.000 is best case for synchronous active chills  
0.028 is good for steady pressure  
0.000 is OK. but also watching the theater two  
weight and amplitude factors here.

0.000 is a good low pressure, but  
0.000

10/8/64

39

May wish to plot

Latency versus distance of Intracellular peak  
to see what happens  
Intracellular crossover  
" peak neg.

Use time of hitloc intracellular peak as zero.  
or possibly time of cpt. 1 peak

did this 10/8/64

---

Plan to run 64795.9069 like 9059  
but with QB=30

---

64795.9062 like 9052 control but with  
~~IFTEST = 15 or 10?? 15~~

and with NT

if I would 250 times values to cover 2.5 T

~~IFTEST = 125/20~~

Then each DT = .01

NT = 251 all else same as before

except IFVE = 0 & delete card 6

approx 550 sec

64795.9064 like 9054 except that  
KTB = 251

approx 580 secs

NT = 251

IFTEST = 125/20

IFVE = 0, delete card 6

PE

rest. Actual

10/8/01

- 9061 140 sec
- 9062 550
- 9063 550
- 9064 140
- 9065 140
- 9066 140
- 9067 550
- 9068 550
- 9069 280
- 9070 280

60 | 3320 sec  
 55.4 min

May work to find  
 location versus air force of  
 Use time of better in  
 or for

10/8/01

Plan to run

like 9022 control but with

TEST = 10 or 10:12

with NT

if would 250 times values to cover 2.5T

then each DT = .01

TEST = 152150

NT = 251 all else same as before

TEST = 0

250 sec

like 9024 with test

NT = 251

250 sec

NT = 251

TEST = 152150

TEST = 0

10/9/64

40

Also do an active & a passive with  $VEF = 6$ .

$SHCF = 0.5$

$PDF = 0.25$

to see what happens

Try this with .9061 based on .9041  $VEF = 12$ !

.9064 based on .9044 use  $VEF = 40$ .

<sup>65</sup>  
• 9066 based upon .9057 for decremental spike  
<sub>66</sub>

• 9069 like .9059 but with  $QB = 30$ ,  
<sub>70</sub>  $20$ !

• 9067 controls for active case  $NSD = 5$  based on 9064  
• 9068 " " " " " "

Best ones  
for plotting

• 9045 passive, long  $Z$ , flat facil.

• 9041 passive, short  $Z$ , flat facil.

• 9059 active, long  $Z$ , shaped facil.  
(large + phase)

• 9044 active, short  $Z$ , flat facil.

Consider rerun with different VEF

.9045

.9041

~~KT~~

ampl in (4)

ampl in (4)

(1) KT = 14 peak = -0.9163

KT

10

(11 better)

-0.53

~~-0.608~~

(2) KT = 18 peak = -1.97

15

-1.39

(3) KT = ~~22~~ = 0.80

19

-0.79

(4) KT = 25 +0.06

~~21~~  
(22)

-0.07

0.08

(5) KT = 27 +0.33

23

0.27

(6) KT = 36 +0.60

28

0.55

(7) KT = 51 +0.43

37

and DT = 0.005

10/9/64 Gradient plots

41

pick KT values, such that m.d. level spike (with PD effect) is

~~①  $\frac{1}{10}$  or  $\frac{1}{5}$  of peak amplt.~~

① ②  $\frac{1}{2}$  of peak amplt.

② ③ peak neg.

③ ④  $\frac{1}{2}$  back

④ ⑤ crossover

⑤ ⑥  $\frac{1}{2}$  to pos. peak

⑥ ⑦ pos. peak

⑦ ⑧  $\frac{2}{3}$  recovery

③ 4 5 6 7 8  $\rightarrow$  9      5 steps

② 3 4 5 6 7 8 9 10 11 12 13 14      10 steps.

Also, 9044 should be spread out.

64795.9061 <sup>passive</sup> based on 9041 but with VEF=12.0, (SHCF=.5) O.K.

.9062 NT=251 <sup>passive control</sup> spont. act. exp. in axonal cpts.

.9063 <sup>passive</sup> similar but with BEB=0.1 in dendrites some does not fire second time

KT=42 axonal firing without soma

KT=100 soma fires first

KT=222 axonal firing without soma

KT > 251 looks like soma will fire first.

.9064 active, erroneous input cards should redo correctly?

have soma & dendrites fired before ~~soma~~ axon because of too much facil

.9065 active decremental conduction case } needs more F.C. ~~or~~ BEB } delay too long.

.9066 Better, but not enough decrement. need larger steps of BJC

.9067 active control with NT=251 & two NES KT=1 and 99

soma dend. fire at KT=7  
again at 106

Then all damped out

.9068 active control with NES=0

soma dend fire at KT=19

beyond KT=210, seem to get an artefactual beginning of local response

.9069 active redo of .9059 with QB=30.

This showed peripheral <sup>dendritic</sup> spike larger than other dend.

.9070 QB=20.



10/19/64 past week was lost to referee work etc.  
 However 10/9/64<sup>-10/12/64</sup> saw the plotting, with Gordon, of a set of transients and gradient plots suitable for final paper. This week is Gordon's last week before leaving for Stockholm. He is working on part of the manuscript, and right now, I will set up the last few computations that we can study together.

The long time calculations revealed that there may be a minor problem at 455 and 462 of WXR93C & 94C which prevent B value from going all the way to zero. This was noted 10/12/64 and we hereby plan to correct this and retest.

Also 451 and 452

Modify WXR 93C into WXR 96C
94C                      97C
795C                    796C

Compare

QB=40                      QB=30                      QB=20

KVE=4	.9059	.9069	.9070
VE neg peak $\phi$ t.4	-2.1031	-2.1132	-2.1402
pos peak	+2.3687 <sub>1.13</sub>	+2.3272 <sub>1.10</sub>	+2.2014 <sub>1.03</sub>
intracell peak in (10)	.9217	.9294	.9370
(14)	.9570 <sub>1.04</sub>	.9603 <sub>1.03</sub>	.9631 <sub>1.03</sub>

Will have to carefully check status of the figures.

10/21/64

43

Wednesday: Today Gordon is in Boston; he will leave at end of the week. Today, I will make a concentrated study of the rough draft as it stands, in order for us to be able to discuss it before he goes.

Sept. 24  
I had previously gone over the text written around figs 1, 2, 3, 4. The new material is written around fig. 5. Return to Begun's now.

Fig. 1

1-A is exp. set up diagram

1-B is anatomical schematic diagram

p. I-A distant for indifferent

1.1 ? "initial" response.

(resistive) location of the distant electrode on this current pathway...  
These impulses travel antidromically...

p. I-B revise according to note A, as follows

1.2 When, for example, the peak of the impulse is at the

(soma) mitral body (point C in Fig. 1-B), ~~current~~ the

soma membrane depolarization, associated with a soma interior whose potential is more positive than all other regions of the mitral cell interior;

(therefore) current must flow (intracellularly) from the soma into the dendrites; this current flows out across the dendritic membrane, and then it must flow (extracellularly) from the dendritic regions (A and B of Fig 1-B) back to the soma at C.

Consider whether we need the term, initial GEC, here?

Monday: Today Professor is in Boston; he will leave at  
 end of the week. Today I will not concentrate  
 study of the rough draft as it stands, in order  
 for us to be able to discuss it before he goes.

24.24

That previously gave over the left written around  
 figs 1, 2, 3, 4. The new material is written  
 around fig. 5. Return to Page 24.24

Fig. 1  
 1-A is exp. set up diagram  
 1-B is anatomical schematic diagram

p. 11  
 1.1  
 distant for different  
 "initial" response

(location) location of electrode electrode on trip  
 two impulses travel intracellularly...

p. 12  
 1.2  
 reverse according to water A, as follows

When, for example, the peak of the impulse is at the  
 (near) central body (unit in Fig. 1-B) ~~the~~ the  
 reverse membrane potential associated with a  
 some interior whose potential is more positive  
 than all other regions of the central cell interior;  
 (therefore) current must flow (intracellularly) from the same  
 into the dendrites; this current flows out  
 across the dendritic membrane, and then it  
 must flow (extracellularly) from the dendritic  
 regions (A and B of Fig. 1-B) back to the same  
 at C.

...with GEC, ...?

10/21/64

44

p. I-3 <sup>1.3</sup> ? Gordon's ? about granule neg etc at bottom

p. II-1 <sup>2.1</sup> mitral bodies, not axon hillock.  
? full series where?

p. II-2 <sup>2.2</sup> triphasic (+ - +), with its negative peak near  
the time of transition from Period I to Period II.

avoid mirror image: are of opposite sign, but otherwise similar in time course. As will be discussed later, the deviation from precise proportionality can be attributed to activity in cells other than the mitral cells.

We will show that the surface negativity of period II can be regarded as a sign of soma membrane repolarization rather than of impulse arrival at the periphery.  
(but Gordon lost this emphasis at 5-9  $\equiv$  VI-7)

Fig. 3 was to be exp. gradient plots. But this led to numerous difficulties in pages 3.1 + 3.2

Decided to skip these problems until later

~~Now Fig. 3~~

The figure number gained can be used to include the full experimental series as Fig. 2 or 3.

~~Plane projection of~~ The apex of the cone, as shown in plane projection in Fig. 4 should really be an angle of only one or two degrees.

p. 34 gives  $A = 800 \mu^2$  & initial cell level  $\approx \rho = 1.3 \mu\text{m}$   
 $\approx 1300 \mu$

$$800 = \pi a^2$$

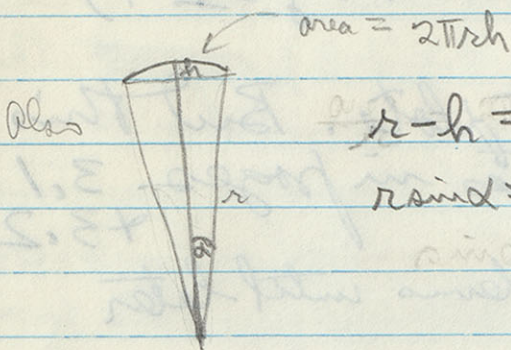
$$a = \sqrt{255} \approx 16$$

total surface area of a sphere is  $4\pi\rho^2$   
 $= (12.57)(1.69) \times 10^6 \mu^2$   
 $=$

A whole sphere subtends  $4\pi$  radians of solid angle

a cone subtends  $\frac{800}{1.69 \times 10^6} = 4.73 \times 10^{-4}$  radians of solid angle

which is  $\frac{4.73 \times 10^{-4}}{12.57} = 0.376 \times 10^{-4} = 3.76 \times 10^{-5}$  of whole sphere



$$r-h = r \cos \alpha$$

$$r \sin \alpha = \sqrt{r^2 - (r-h)^2}$$

$$A = \pi r^2$$

$$a = \sqrt{800/\pi} = \sqrt{255} \approx 16$$

for  $\alpha$  very small, here approx  $\alpha \approx \sin \alpha \approx \frac{a}{r} \approx \frac{\sqrt{A/\pi}}{r} \approx \frac{16}{1300} \approx 1.23 \times 10^{-2}$

for every other cell  
 get  $2\alpha \approx 3.5 \times 10^{-2}$   
 $\approx 2^\circ$

$2\alpha \approx 2.5 \times 10^{-2}$  radians = 0.025 radians  
 $\approx 1^\circ 30'$

see next page

10/21/64

45

Page 4.1 dealing with Fig. 4 of cone model  
Justification of cone can also rest upon my  
separate paper.

~~✱~~ We could do a quick calculation of true cone size <sup>solid angle</sup>  
i.e. here the solid angle has been exaggerated.

Second ¶ of p. 4.1 might want to be turned around.  
Also, should include possibility that only half the  
cells fire, but fairly uniform density of active cells.

dorsal & ventral layers not clear enough in center & then  
"in through dorsal hemisphere & out through ventral  
hemisphere" or something like that.

p. 4.2 footnote & bottom. The model ~~approximates~~ involves only  
~~one~~ concern to — The model includes one  
feature which corrects for departures from spherical  
symmetry, otherwise, the simplification of spherical  
symmetry is assumed. This one feature is an  
external leakage path from the center to the  
outside.

bottom ¶ confusion may result from  
pairing - better treat each separately.

p. 4.3 ? confusion between current & resistance labelling,  
are we using ind or dist?

from p. 34

1200 mitral cells per  $\text{mm}^2$  seems to imply  $\approx 25,000$  mitral cells per bulb,  
which is probably Gordon's  
starting point.

Solid angle of each cone  $\Omega = \frac{4\pi}{N} = \frac{12.57}{25 \times 10^3} \approx 0.5 \times 10^{-3}$  radians  
of solid angle

for  $N = 12.5 \times 10^3$  get  $\approx 10^{-3}$  radians of solid angle



also, in radians, circular area for  $\alpha$  small is  $\pi \alpha^2$

$$\pi \alpha^2 = \frac{4\pi}{N} \quad \text{or} \quad \alpha = \frac{2}{\sqrt{N}}$$

•• for  $N = 25,000$ , get  $\alpha \approx \frac{2}{1.6 \times 10^2} = 1.35 \times 10^{-2}$  radians  
 $\approx 0.77$  of a degree

for  $N = 12,500$ , get  $\alpha = \frac{2}{1.12 \times 10^2} = 1.78 \times 10^{-2}$  radians  
 $\approx 1^\circ$

ie. when half the mitral cells are active, ~~the effective~~ there are 12,500 cones  
each of whose elements of surface makes an angle of about  $1^\circ$  with  
the axis

$$1^\circ = 0.01745 \text{ radians}$$



10/21/64

46

p. 4.4

? axons do not carry inward?

If the reference electrode were placed at the dendritic periphery (A) instead of at DIST (or GD or  $\infty$ )

This explains the opposite polarity (or sign) of the potentials  $\phi$  (C) and (A) in Fig. 2

p. 5.1 need only assume no

assume that there is no current through the external resistance loop, and that the reference electrode is at the same potential ~~as~~ as if it were at ~~the~~ the surface of the bulb or at the glomerular level (A).

p. 5.2 top  $\Pi$  no.

axon in oil;

$$\frac{\partial V_e}{\partial \rho} = \frac{-r_e}{r_i} \frac{\partial V_i}{\partial \rho}$$

where  $r_e$  is a fun of  $\rho$

$$V_e = \int_{\rho=\Pi}^{\rho=x} \frac{\partial V_e}{\partial \rho} d\rho$$

$$= \frac{1}{r_i} \int_{\rho=\Pi}^{\rho=x} r_e \frac{\partial V_i}{\partial \rho} d\rho$$

due to initial  $q_e$ ?

? ~~core~~ cross section

p. 5.3

why use both  $r$  and  $\rho$ ?

$$V_{e2} - V_{e1} = \frac{I R_e}{\Omega} \int_{\rho_1}^{\rho_2} \frac{d\rho}{\rho^2}$$

Better make a table for the paper.

pot. divides this way because same current flows all around of these are in series, and DIST represents (zero) reference point.

Give a numerical example <sup>multiple body level (MBL)</sup>

Suppose  $V_e$  at MB is 2.5 mV neg. rel. to  $V_e$  at glomerular level (Gh), then the 1:4 ratio of the resistances of external path means that ~~the~~ MB is 2.0 mV neg. rel. to DIST, ~~and~~ while ~~DIST is 0.5 mV neg. rel. to Gh~~  
Gh is 0.5 mV pos. rel. to DIST.

10/21/64

p. 5.4

GL to MBL

47

The amount of current will be  $\frac{1}{25}$  of that flowing within the cone, <sup>from A to C</sup> or  $\frac{1}{26}$  of the total current flowing from ~~the glomerulus~~ A to C. <sub>GL to MBL!</sub>

maybe 5.5 should come first in the text, since it is the most important and has already been mentioned. The other two could go into fine print.

~~It~~ seems to confuse surface record and glomerular level record.

Instead of ABC levels, How about

Surf	
GL	GL
D	PL
MB	MBL

p. 5.6 Perwood II <sup>membrane</sup> put repol. of soma first. & then put passive electrotonic or active depol. of dendrites -

avoid source sink terminology  
place emphasis upon current flow.

It wouldn't matter if the soma were a source for axonal current flow, you would not see any pot. unless dendrites were also a source.

$G_{\infty} = \frac{1}{25}$   $\therefore$  current flow due to Action Pot. voltage source. is a negligible  
i.e. have to consider the rel. amount of extracell. current generated.

The amount of current will be 1/2 of that flowing  
 within the case, or 1/2 of the total current  
 flowing from ~~the source~~ A to C.

may have to refer to a later  
 discussion as to why  
 the conventional interp  
 of this pos. is incorrect  
 because periph distributors  
 are not sources, esp  
 in case of .9045

At present, matter of the same was a source for current  
 and flow, you would not see any pot. when distrib  
 were also a source.

$R = \frac{1}{2}$  ∴ current flow due to return pot.  
 Voltage source is a negligible  
 ∴. due to counter the return of current.  
 Current generated.

10/21/64

48

p. 5.7 It is misleading to say the the surface pos. of period I is due to the terminal dendrites acting as sources during some invasion;

It is due to pot. divider effect of some neg. which is due to extracell. current flow from PL dendrites to soma (but not vice. from periph. d.)

This provides a good transition

(Look at the gradient plots to consider more carefully.)

no, not simply a fraction.

Then all records would have exactly the same time course and differ only in magnitude or sign.

p. 6.1 characteristic length ( $\lambda$ )

$$Z_L = l/\lambda$$

I believe that elsewhere  $X = x/\lambda$

∴ this  $X$  here is not consistent;

$$Z_L = \int_0^{x_1} \frac{dx}{\lambda}$$

$$L_1 = l/\lambda = X_e$$

$$Z_L = Z_e$$

But 1959 paper used  $l/\lambda$

Care in dealing with  $Z$ ,  $R_{in}$  &  $R_i$  actually better include also  $R_e$

Discussion of Fig. 6 needs more emphasis upon positive aspects.

also, fact that facil needed to prevent blocks. also that dendrite firing lat reverses?

part 1 - This is intended to say the no surface pass. of part I is due to the terminal surface being on surface being some interval;

It is due to get derivative of some way. which is due to interval. which is from part 1. derivative to some interval (but not sure, from part 1). (look at the derivative of the to consider more carefully.

up, not simply a factor. The all variables must have same factor. Some time some are different in magnitude or sign.

Local characteristic length (L)  $L = \lambda / \alpha$  where the clearance  $\lambda = \lambda / \alpha$   $\therefore$  this  $L$  has in not constant.

$$\lambda = \lambda / \alpha$$
$$L = \lambda / \alpha$$
$$\lambda = \lambda / \alpha$$

But 1981 paper used  $L/\lambda$

Case in dealing with  $R$ ,  $R_m + R_i$  centrally better include also  $R_e$

Dimension of  $F$  is  $\lambda$  which is more complex than previous systems.

also, let the full needed to point about, also that derivative of  $L$  is  $\lambda$ .

10/23/64 Windup Notes, esp. re figures

49

Fig. 2 - order photography of exp. series  
10/5/64 <sup>to photo</sup> longest dimension (image) on print to be 9"

\* Fig. 1-B modify on print, leaving out tufted & putting  
11/5/64 <sup>to photo</sup> in collateral. Also GL, PL, MBL.

~~11/7/64~~ whereas Fig. 2 will use words to designate layers.

Fig. 3 still needs to be prepared. (Gordon has done this 10/26/64) ✓  
11/5/64 <sup>to photo</sup>

Fig. 4 W.R. finish this fig. after paper is completed.

\* Fig. 5 3 records (Intra, Extra, Recorded)  
Could be done before Gordon leaves.

Fig. 6 Probably replace 9059 Four Theoretical Transient Series  
also 9041 & 9044 could have interpolated  
smaller compartments.  
Do new computations, plot with Dorothy & assemble.

Fig. 7 Latency versus Distance Plots  
These will be changed when  $\left. \begin{array}{l} 9059 \\ 9041 \\ 9044 \end{array} \right\}$  are redone

I told Gordon that I would write the text for  
this section. He did have a start.

Whitney Motor, exp. no. 1000

Fig. 1 - order photograph of exp. series  
11/1/04 (largest dimensions) or print to be 9"

Fig. 1-B available on print, bearing out title of printing  
11/1/04 in lateral. Also G.L., P.L., M.B.L.

Series Fig. 1 will be made to separate layers.

Fig. 2 will need to be printed. (Order has been in 10/26/04)

Fig. 4 W.R. finish this fig. after paper is completed.

\* Fig. 5 Brackets (inter, extra lateral)  
could be done before Gordon leaves.

Fig. 6 Probable copies 2029  
also 2041 & 2044 and have interphases  
smaller components.  
The next copy should be put into printing tomorrow.

Fig. 7 Interm. series Distances Plot

These will be changed when 2029  
2044 are ready  
2045

I had planned to work with the cut for  
this section. It did have a start.



10/23/64

50

## Fig. 8 Theoretical Gradient Plots.

see p. 41

? how to label times

characterized by following points of the MBL  
Theor. transient.

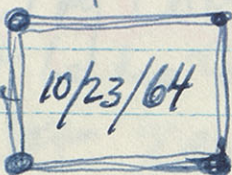
I-a	early I	approx 1/2 of neg peak ampl (before peak)
I-b	peak I	approx peak neg.
I-c	late I	approx 1/2 back down
I-II	transition I-II	approx crossover
II-a	early II	approx 1/2 to pos peak
II-b	peak II	approx pos. peak
II-c	late II	approx 2/3 back down

need to redo Theor with  $DT = .005$  or smaller  
possibly  $DT = .002$  + tables only.

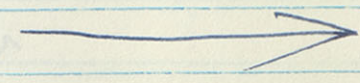
Fig. 9 Experimental gradient plots for comparison.  
Use same seven points in time  
based upon the ~~the~~ MBL record.

The range from surface (0) to 0.3 mm  
depth, Gordon says is not well  
documented. He kept moving the  
microprobe in until he saw  
an obvious change. Thus, he did  
not document the very small changes  
between surface and GL

These plots were done 10/23/64



Evidence against 9044 synch. dendrites  
with large VEF



Because this has too large a deep gradient at early times

However, primary - secondary dendrite smear would  
reduce this!

10/26/64 Comparing gradient plots  
Figs 8 & 9

Fig. 8 .9045, 9041, 9059, .9044

Fig. 9 prelim.    Mar 30, Prod 2  
                          May 16  
                          May 2 (illustrative series)  
                          April 12 Prod 3, less complete

General comments exp plots  
we took 0.3 mm depth is negligibly different  
from surface ~~of them~~.  
    ↳ this was true of Mar 30, Prod 2  
    but not of others.

May wish to plot only from Gh.

Difficulty is that gradient from surface to Gh  
was not fully documented. May include this in  
Stockholm series. But here, best start  
from Gh to MBL to deeper.

Thom II - a Time of Mar 30 Prod 2  
          & II - b of May 16

earlier records show small gradient for depths greater than MBL  
but later records show large pos. slope near MBL  
in some cases from MBL deeper  
in others its Pley to MBL

Small gradients can be explained by  $CORE \approx 1/25$

∴ large gradients cannot be due to initial apions

& this is evidence for granule GEC.

II  
I  
to

10/20/04 Company's significant plots  
Fig 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

Fig 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

Fig 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

Fig 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100

May 31

Anterior  
Prod#1

Posterior  
Prod#6

soy 0.7mm

I-a 1.5 msec		I-b 1.8 msec	I-a 1.5 msec		I-b 1.8 msec
depth			depth		
0.46	-2	-6	0.25	+1	-2
0.70	-2	-12	0.47	-1	-13
0.82	-4	-11	0.56	-4	-22
1.02	-16	-36	0.67	-12	-37
1.14	-25	-41	0.76	-24	-41

ampl. GL  
MBL

10/26/64

52

Early gradients all agree on curved flow from dendrites to soma.

Theoretical gave more indication of zero gradient for outer half of dendrites than do the expt.

exp ones do all show steep gradient for ~~dendritic trunks~~ prox dendrites than periph.

Now think of primary - secondary smear.  
does not seem to explain differences

But how about departure from spherical synchrony?



later firing cells could have their cones act as pathway for earlier firing cells & thus would fail to show zero gradient that would be present in peripheral cones when truly synchronous.

This hypothesis could be checked experimentally by comparing records in anterior & posterior part of bulb

Jordan's study of May 31 (1960) does seem to fit this hypothesis

axonal GEC can be estimated by experiments which block mitral cells.

Note that axon <sup>main phase</sup> GEC is curved from ~~MBL to GL~~ <sup>GL to MBL</sup>

Whereas granule GEC is from MBL to GL

\* Records obtained when mitrals block, should provide an approx. to off-axon GEC effect, except one must remember that if mitral cells are not invaded, they would not provide dendritic E to granule cells & granule cell GEC would be different. Gordon does have some exptl. results on this & could try for some more. ie. with two per sec, sets block every other time. Needs faster sweep to see well. Should be looked into. See pp 54 & 55

10/26/64

53

I-b exp. records do not have surface pos. to theoretical ones  
& this reduces gradient.

Presumably offered by GEC accounts for this.

ie. it pulls surface neg by some fraction  
of the deep neg.

~~Not the case with April~~

I-c exp. gradients are nearly flat

pressure theoretic dip at MBL

shaped active dips of cpts. 8 } indicative of  
synchr active dips of cpts. 5 } dendritic firing.

I-II transition (MBL at zero)

even pressure cases have neg dip (PH)

prox. dendrites same as  
pressure notes for repol. soma  
& for the less depol. dendritic  
periphery.

.9044 does not dip.

exp. ones show very slight dip as well as  
a general gradient from MBL to GL  
which must be early granule GEC

II-b & c theoretical show gradient from MBL to GL  
but very little deeper than MBL

exp. show domination by granule cell <sup>GEC</sup> gradient.

I-V p. results don't have surface gas. In theoretical one of this surface problem.

Probably offered from GTC meant for this.

is. If this surface was by some problem

and lots of the deep way.

~~of the surface was not~~

I-C effect problems are usually that

problem. Theoretic says it will

be a surface layer of 0.8

rough surface layer of 0.8

I-II transition (MRL to gas)

even further away from surface (PL)

Max. surface roughness

rough surface for rough. some

of for the low depth. boundary

roughness. roughness. roughness.

roughness. roughness. roughness.

roughness. roughness. roughness.

roughness. roughness. roughness.

roughness. roughness. roughness.

roughness. roughness. roughness.

roughness. roughness. roughness.



10/26/64

Dr. Gordon Shepherd  
 c/o Dr. David Ottoson  
 Fysiologiska Institutionen II  
 Karolinska Institutet  
 Stockholm 60  
 Sweden

Look back at extracellulars for antidromic blocks

See p. 30  
64795.9053 blocked

	off. 1	2	3	4	5	6
intracellular <sup>peak</sup> spike	.941	.939	.918	.170	.153	
KT	6	9	12	15 & 16	17	

did not die and properly.

zero and cond, peaks	-.222	-.286	-.337	-.236	-.153	-.09
KT	14	12	13	15	15	16

p.d. factor = .25	-.177	-.246	-.292	-.189	-.107	
KT	13	12	13	15	16	

amplitude of peaks neg is about 15% of that for unblocked

\* Reread page 29 \*

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 Sweden

Labels under the microscope for extraocular muscles

see p. 50  
 PM 1982.1023 - labeled

KT 6	140	141	142	143	144
KT 6	140	141	142	143	144

did not do anything

KT 14	140	141	142	143	144
KT 14	140	141	142	143	144

KT 12	140	141	142	143	144
KT 12	140	141	142	143	144

Labels for extraocular muscles

Posterior eye muscle

10/26/64

another blocked case is 64795.9032 see page 17

	1	2	3	4	5	6
Intracellular peak	.94	.93	.91	.143	.128	.117
KT	6	9	13	16	17	18

decay progressively

Zero Shunt Conduct.

neg peak	-.183	-.25	-.302	-.1905	-.123
KT	14	13	14	15	16

This is about 15% of unblocked (see .9031)

and occurs close to time of hillock spike peak

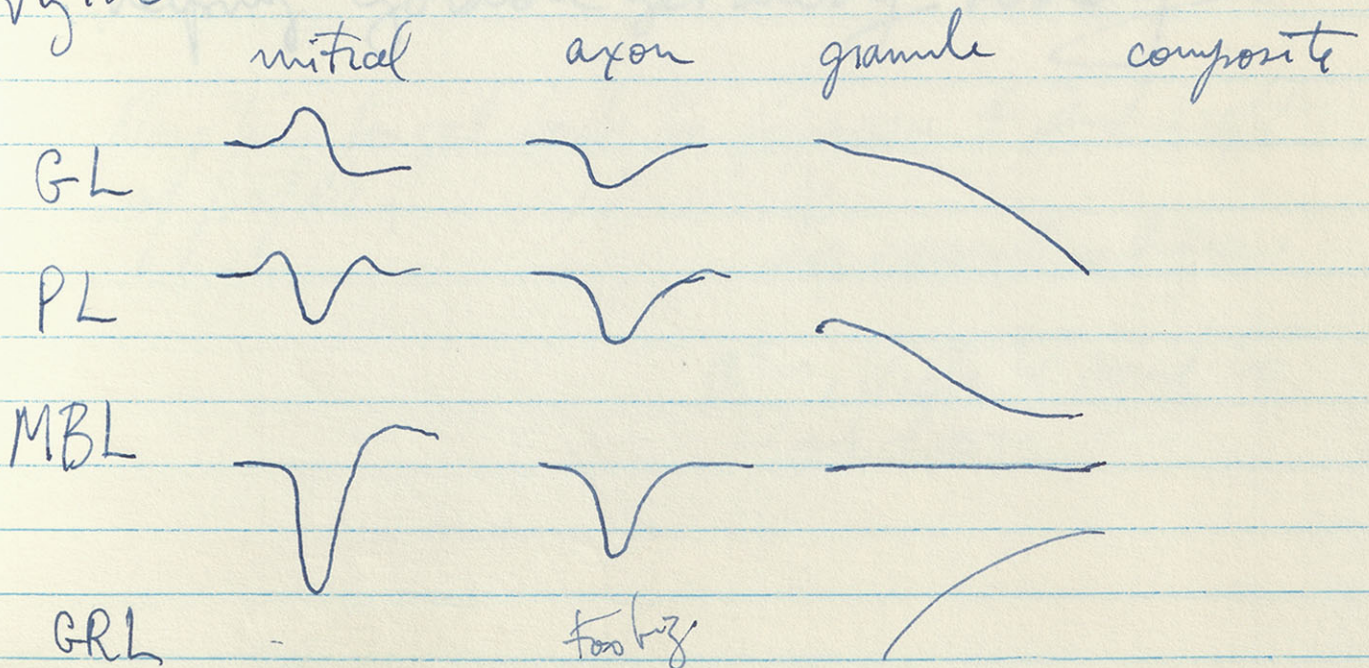
which peaks at KT=18

ampl = -1.87

similar result with block in .9023

also .9022

Fig. 10 Could be included in Discussion



and then label case in 04592.9032 see page 17

1	49.	49.	49.	49.	49.
2	93.	93.	93.	93.	93.
3	91.	91.	91.	91.	91.
4	143.	143.	143.	143.	143.
5	158.	158.	158.	158.	158.
6	177.	177.	177.	177.	177.
KT	18	18	18	18	18

handwritten scribble

see page 17

KT	14	13	14	12	10
183	-183	-183	-183	-183	-183
14	-14	-14	-14	-14	-14
13	-13	-13	-13	-13	-13
14	-14	-14	-14	-14	-14
12	-12	-12	-12	-12	-12
10	-10	-10	-10	-10	-10

this is about 12% of unlabelled (see 9031)

and some case to find of 183

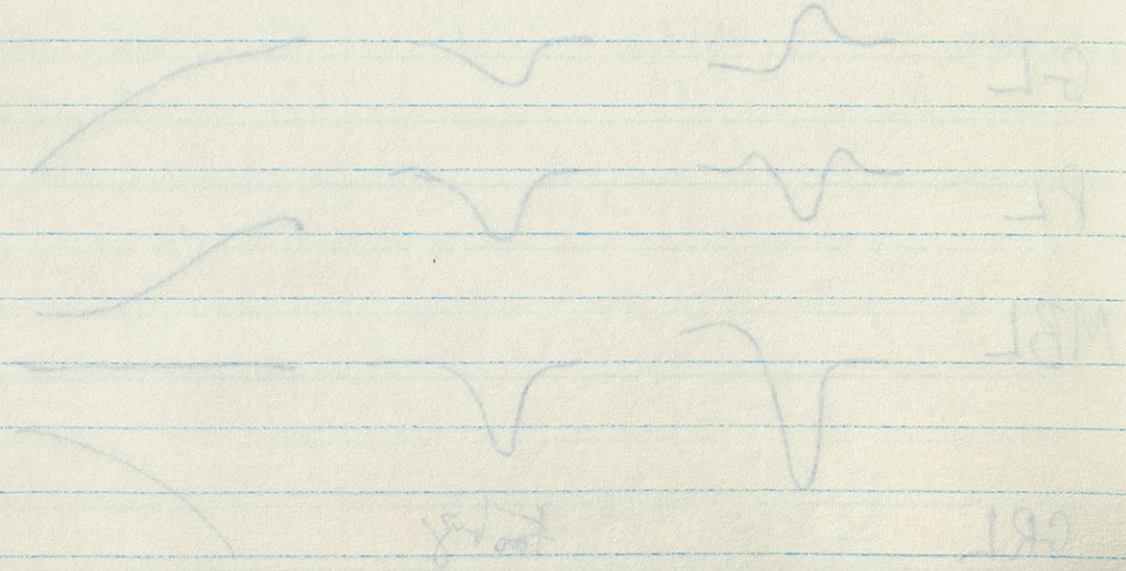
what page 2 KT=18

18.1 = -1.87

similar result with label in 9032 also 9032

could be included in Discussion

initial open granule composite



10/27/64

56

Since it is probable that paper II will appear significantly later than paper I, perhaps we should say a little about granule and axon superposition with initial & present one or two tentative reconstructions.

Paper II would go into more detailed discussion & justification & perhaps also other kinds of plotting.

Inspection of Gordon's blocked mitral cell records shows a residual peak that is one third to one half of that with invasion.

---

Did successful reconstructions between helpway Gordon get away today

Since it is possible that paper II will appear  
 important later than paper I, perhaps  
 we should say a little about general and  
 more specific information with respect to present  
 one or two interesting recent questions.

Paper II would be more detailed discussion  
 of specific question & perhaps also other  
 kinds of plotting.

Discussion of Gordon's Method  
 which will be made when a suitable field  
 that is suited to our help of that with minor.



But successful recent questions between  
 Willy, Gordon get away today

10/28/64 - 11/2/64

57

after Gordon's departure

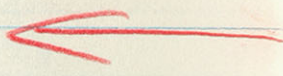
- ① rearranged bookcases to provide for additional storage
- ② Put all Aitken data analysis away together
- ③ Collected information on Federal Employee Health Benefit program for presentation at Assembly Meeting.
- ④ Prepared memos on same
- ⑤ Prepared semi-annual report on "Scientific Accomplishment"
- ⑥ Sent reprints to several record requests.
- ⑦ replied to Fender's Cal. Tech invitation
- ⑧ replied brief note to Stark re Gordon Conference

Now time to get back to figures & 2nd draft of papers.

↓  
esp. reconstructions.

also, photo to send to Gordon

What works as a justification for  
disphasic approval contribution





11/4/64

58

Today completed a final pencil version  
of superposition

Remarkably  
Successful

- ← A. nitrol 64795.9041  
+ B. axons diphasic graded  
+ C. granule similar to computed  
= D. Superposition

for four depths GL, PL, MBL & GRL

Also fixed time dotted baselines of Fig. 2  
to be ready for photography.

Also fixed figure 1-B to provide  
horizontal collateral #6  
and short axon #7

as well as level designations GL {  
PH {  
MBL {  
Also "GLOMERULUS"  
inside the circle.

Today completed a final final version  
of Superposition

Superposition

A. Mutual #4792, 2041

B. others - different order

C. granules similar to compound

= D. Superposition

for four dates GR, PL, MBR & GRL

Also tried time dated location of fig. 2  
to be ready for photography

11/11/04

Also tried figure 1-B to provide

horizontal column #6

and that one #7

as well as level descriptions GR }

PL }

MBR }

Class "GLOMERULOS"

insert the circles

11/5/64

59

Completed, with black tape & Leroy lettering,  
& took to Photography.

I - Fig. 1-B diagram

II - Fig. 2 exp. series

III - Fig. 3 Three records with Periods I, II, III.

Also, took to Medical Arts The pencil figure 10  
which shows Superposition (see previous page)

---

Now, must set up additional calculations with  $DT = 0.002$   
for 9041, 9044, 9045, 9059 if NT sufficient

↓ need smaller cpts.

↓ 9160  
replace with  $QB = 25$ ?  
& with end cpt  $\mu_{jj}$  same as for others.

see over

See p. 42

Revise text - see pp 43-48 of this notebook.

Halving dendritic cpts doubles ~~GD~~

here i.e. for  $\Delta Z = 0.1$ , get  $UD = 100$   
for  $\Delta Z = 0.05$  get  $UD = 400$

See pp 61-62 of book 3

Factor of four can be seen as

$$UD = \frac{GD}{CD} = \frac{\text{double}}{\text{half}} = \text{four times}$$

$$USD = \frac{GD}{CS} = \frac{\text{double}}{\text{unchanged}} = \text{double}$$

12/14/64 refer back to book 3 p. 62 & ahead to p. 82 of present book

10 cpts.  
suppose now  $LD = \frac{1}{2} LA$ , because  $LA = LD$  for 5 cpts

$$\text{then } \frac{UD}{UA} \neq \frac{DD}{DA}$$

but  $\frac{UD}{UA} = \text{four times previous}$

But I already got this from  $(\Delta Z)^2$  ~~argument~~  
consideration

$$\frac{USD}{USA} = \frac{GD}{GA} = \text{twice previous}$$

but then this changes  $\lambda_{ij}$

11/5/64 Setup new runs

60

64795.9141 based on 9041 with more dendritic cpts & <sup>sadder</sup> DT

1 64795.9141 25 251 8 .002 .05 0 0 0

2 0

3 25. 400. ~~25~~ 400. 1. 3 10 0 ~~1001~~ 1111 +1

4 5. .0 .0 .0 .3 .3 .3 .3 - - - - - ten of these

5 600. 5. 100. 25. 40. 5. 50. .10

6 4. .25 .2 1.3 1.7 .04

Also let 64795.9142 be the same except that

card 3 has effect = 1001

card 4 has VEF = ~~3.33~~ 4.77

$$(4.0) \left( \frac{20}{14} \right) \left( \frac{5}{6} \right)$$

64795.9144

1 " 251 8 .002 <sup>.05</sup> 0 0

2 0

3 25. 400. 5. 400. 1.0 3 10 0 1101 -1

4 5. .0 .0 .1 .1 - - - - - eleven of these

5 400. 1. 25. 20. 40. 5. 40. .10

6 4. .25 .1112 1.3 1.7 .04

HH+99 .0 .0 .0 .01 - - - flat - - -

HH+99 .0 .0 0 all zero

9143 could be the same with QB = 25.

Expect  $\approx 120 + 180 = 300$  secs for 9145  
9160

But other two will be 4X as much in the  
Rung Kutta - Maybe 600secs each

<del>no. for</del>	roughest. time	pages	Actual time
<del>9141, 9144, 9160</del>			
9141	600	28	411
9144	600	28	
9145	300	23	250
9160	300	28	342
	60   1800	102	
	30		

11/5/64

61

64795.9145

1           "           251    2   .002   .1   0 0 0

2 0

3 as before 25. 100. 2.5 100. 1. 3 10 0 (1101) +1

4 .5 .0 .0 .0 .25 - - - flat - - -

5 600. 5. 100. 25. 40. 5. 50. .10

6 4. .25 .1112 1.3 1.7 .04

64795.9160 based on 9059 but with  $\Phi B = 25.$

1           "           251    2   .002   .1   1 0 0

2 0

3 25. 100. 2.5 100. 1. 3 10 0 1111 -1

4 5. .0 .0 .1 - - - flat residual fail

5. 400. 1. 75. 20. 40. 5. (25.) .10

6. 4. .25 .1112 1.3 1.7 .04

+1+1+99 .0 .0 .0 .0 .04 .03 .02 .01 - -

+1+1+99 - all zero

Cards ready 10:30 AM 11/6/64

Now look at program revisions sep. 42

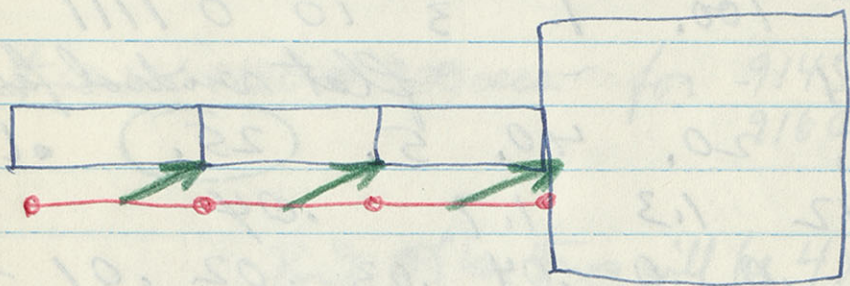
mod. 451, 452, 455, 462 & program numbers

Also get rid of RINC & RINB in main program (anachronistic)

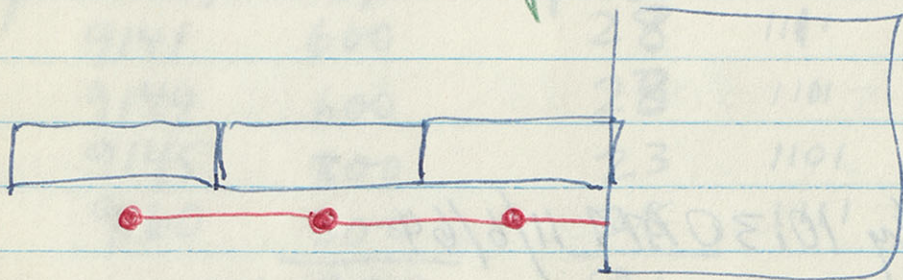
Also, using matching ARGS & put Equivalence statements in Subroutines  
This did not work

Done  
11/6/64

2/21/67  
use FAC = 2.0  
and later plan to  
fit into input format



Red represents core resistance, and when assigned to connections as shown in green, we get what has been used so far.





11/6/64

62

Just modified WXR 795C  $\rightarrow$  WXR 796C  
93C  $\rightarrow$  96C  
94C  $\rightarrow$  97C

Cleaned up old RINC & RINB, also QUENCH: QENCH A  
& GD: GD etc. taken care of by Subront. exp

Most important changes were.

(A) smaller tests at 455 & 462 to prevent fictitious local response in the long period runs.

? \* (B) put in factor of (2) at 451 & 452 to make  $\mu_j$  the same for end compartments as for in between compartments.

Rationale ~~is that~~ was that  $g$  would be twice as great at ends, but not so sure now.

Really ought to be treated by the more careful method Jim uses for lumping.

The intuitive argument is fairly clear for doubling  $g$  at the axon soma junction, but this was not, in fact, done.

Better Ponder & Reconsider this.

Just modified WXR 792C → WXR 792C  
93C → 93C  
94C → 94C

Cleaned up old RINC & KINS, also DIRECT: GENCHA  
& GD: WDR. totum  
copy of 28000000

Most important changes were...  
A smaller bit at 425 + 425 to prevent  
first from local response in the  
period some.

B \* ?  
put in folder of (2) at 421 & 422  
to make 11/11/11 and 11/11/11  
as far in 11/11/11.

...and that of 11/11/11  
...and that of 11/11/11  
...and that of 11/11/11  
...and that of 11/11/11

The instruction organization fairly clear for  
...and that of 11/11/11  
...and that of 11/11/11  
...and that of 11/11/11

11/10/64 got results on 64795.9145

63

see p.61

9141

9160

9144 did not run because of error in cards.

.9145 agrees with 9045

The extra time values will be a help. The gradient plots were probably close enough.

.9141 does not agree exactly with .9041

This shows even in the intracellular values of compartment ①. Examine more closely.

UA & USA are 25. and 5. in both cases

UD & USD differ

in 9041	UD = 100.	USD = <del>200.</del>	<del>these</del> NSD = 5
9141	UD = 400.	USD = 400.	NSD = 10

∴ in 9041,  $U_{ss} = 206.$  } this is probably not desirable  
in 9141,  $U_{ss} = 406.$  }

should leave USD same as before and change only UD

Therefore set up 9241 with USD = 200., UD = 400.  
also 9244 " " "

Also, set up 64796.1160 to test new program on this question of large and intracellular spike.

Ed  
This <sup>speech</sup> will be published in book "Nerve as a Tissue"

Sir John Eccles' dinner speech was rather interesting.

focused on reminiscences, scientific method, scientific spirit + tremendous scope + future for neurophysiol.

a) commented on how fortunate he had been to join the Derrington school at this peak of the classic neurophysiol. era. No subst. for working with a great scientist.

b) commented that he had uncritically accepted the erroneous inductive concept of scientific method which purported to get results from an accretion of data. That (around 1945) he had been very depressed when he realized that data was disproving the electrical hypothesis for neuromuscular junction, where he had pretty completely committed himself to the electrical hypoth. (i.e. he felt that a cherished belief was being

c) destroyed) <sup>Karl</sup> Popper saved the day for him by convincing him that science progresses through the falsification of hypotheses. The disproof of a hypothesis should be a cause for rejoicing, rather than despair. This gave him a new lease on life, but, of course, he prefers to be the one who disproves his hypothesis. He was very definite that hypotheses should not be secure, but that they should be definite & clear & provide a clear target to be shot at. He also praised

d) the free level of personal communication amongst neurophysiologists; implied that there was remarkably little petty competitiveness - rather paradoxically pious in view of his own record. Said that friendships continued in spite of sharp scientific disagreements. He also commented that it is better to be challenged in print than to be ignored.

e) he ended on the note one reason for the lack of bitter competitiveness + lack of trying to keep a problem to oneself, is that there is so much to be done. There are enough problems for everyone, the field is wide open. Each success opens up more. The program of understanding the mechanistic aspects of the brain extends at least several generations into the future; into the next century or more. He implied, but did not dwell on the thought that the "brain-mind" problem could be postponed that long. He was, in fact, fuzzy, re brain-mind distinction. see next pg

11/16/64

64

Just returned from Nerve and Tissue Conference

Saw Sir J. & Mrs. E. Cole, Winzler, Schoeffle, Curtis, Hubbard, Willis, Van der Loos, Farley, Stanley Crane, Bornstein, Barbara Rankin, Brindley  
↳ ? Goldstein?

Palay - glia coat dendrites except at synapses  
at synapses, glia seem to envelope synaptic pairs & isolate them from synaptic groups or other dendrites.

showed slides with glia blebbed in to show how ubiquitously it fills spaces between dendrites & axon terminals.

Yet, he is ready to allow for 5 to 15% extracellular space. Robertson has seen some much more open. He is doing some expts. to purposely open things osmotically.

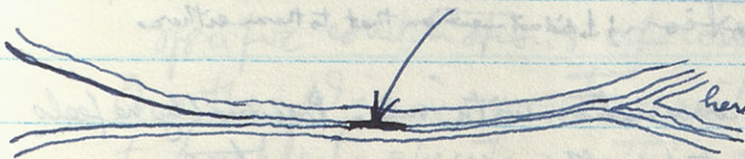
Pappas - Bornstein, Cohen, Bennett

They have shown electrotonic synapses in tissue culture of embryo mouse cortex.

They see axo-axonic  
soma-somatic  
electrotonic

Jens.

Double membranes come together & their hydrophilic layers seem to fuse at so-called electrotonic



here we have double membrane of glia

standard synapses have granules on presynaptic side. Electrotonic ones don't.

40  
set through this dinner with Curtis & Hubbard & Willie & Barbara Rabin.

Curtis & Hubbard chuckled at many points (The atmosphere was already genial from cocktails & from "old goat" speaker previous).

at end of talk, Curtis turned to Hubbard during the clapping & said, "and he does it all on ginger beer".

I could sort of join in the feeling with Hubbard, afterwards, that they were well aware that JEE does not live up to all these pious phrases, but that, nevertheless, they do admire him, and that many of the pious phrases are worth emphasizing even if he doesn't live up to them. In other words, he does give lip service to & even largely believe in the right sort of values.

However, it was also apparent to me that Curtis & Hubbard survive at Canberra because (1) they are very good, (2) they try to be independent (3) they are able to laugh at the big man's many foibles & they seem to do this all the time.

They mentioned many times how impressed they were with Lloyd for having been the first to reply to the Festchrift invitation & the first to send in his manuscript. With regard to profit from Eales Spritzer volume, they commented that he had given 900 copies away.

They were aware that after Eales had done his hatchet job on Lloyd, he had pressed Coombs to dig out the old records relevant to my paper & had carried the same mood over to that. They did not seem to be aware of his attempts to block <sup>my</sup> publication; I did not mention that to them either.

It was my impression that he evaded conversation with me. Presumably he feels guilty & does not wish to be confronted with embarrassing questions.

11/16/64

65

Set up new production run.

64795.9241 like 9141 but with USD = 200.

also 64795.9244

"

and add missing card of 9144

set up 64796.1160 as test, need to satisfy CRT limit

---

Received today, letter from Ramon-Moliner

He regards Fujita's cells as "preamplifiers" of the nervous system & he likes my safety factor argument for making this a redundancy device. He does not mention the idea I wrote to Pat Wall in 1961 regarding protection against noisy endings, but he does say that preamplifiers should be ~~slow~~ slow noise. He also calls attention to the granule cells of the olfactory lobe as having only dendrites and wonders how they might function. This makes me wonder if I should not write two short notes to *Science*, one on this low noise-redundancy idea (with references to personal communications) and one on the granule cell idea.

Also, today, I was thinking about the application of my dendritic models to nerve nets & the fact that one needs to set-up specific combinations of connections for specific purposes. One thought is in connection with pattern recognition. One ought to be able to specify a pattern of connections that would recognize circles of certain radius, for example. Thus, ~~down~~

... 200 = 220 ...

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11/16/64

66

down stream from receiving zone, there would be a cell, or a group of cells which would respond only when the excitations & lateral inhibitions were such that they satisfy the constraints for a circle of this diameter, whatever its precise location. Slightly different group of cells for circle of different diameter.

If circle broken, or say, a semicircle, this would be indicated by additional cells.

Try to define this.

Let  $O_{10}$  designate a cell responsive to circles of radius ten units.

Digress for a moment, note that dendritic location of endings would permit also the temporal sequence along a curve to be detected. It is possible that the Hubel & Wiesel lines have a directional aspect that has not been looked for. <sup>sequence</sup>

Array the primary neurons (or retinal cells)  $P_{11} P_{12} P_{13} P_{14} \dots$   
 $P_{21} \dots \dots$

Each secondary neuron could, even, disregarding dendrites, have input  $SI_k = \sum_{ij} A_{ij} P_{ij}$

Circle secondaries would be those for which  $A_{ij}$  of significant mag. would have  $ij$  pairs satisfying circular locus in the  $ij$  plane. This would be OK as purely formal, but it would be nice to give more detail about how achieved.

have shown from previous work, there would be a cell  
 as a group of cells (some would be in the  
 water of lateral inhibition were such that they  
 state the resistance for a circle of the diameter  
 diameter its phase location, slightly different  
 groups of cells for circles of different diameter.  
 If circle diameter was say a certain circle  
 this would be indicated by shift of phase cells.

Try to define this

Let  $\phi_0$  designate a cell response to circle of radius  
 $r$  units.

Diagram for a neuron, not that inhibitory location  
 of pathway would point also the temporal response  
 above a curve to be detected. At the possible  
 that the lateral inhibition has a directional  
 aspect that we not been looked for.

Group the frequency curves (actual cells) for P. P. P. P.

Each curve represents cell in same frequency band, same  
 input  $Stk = \sum_{i=1}^n H_i P_i$

With similar results the frequency of response  
 would vary if four different cells were in  
 the response. This would be the response for a cell  
 would have to be considered that has a certain

11/17/64

67

### Remarkable coincidences

① Ramon Moliner's letter received yesterday raised subject of grundle all which Gordon & I had discussed.

② middle of p. 66, yesterday, postulated temporal sequence. Today, new copy of J. Physiol. has a paper

Barlow, Hill & Levick

J. Physiol 173 377-407 (1964)

"Retinal Ganglion Cells Responding Selectively to direction and speed of image motion in the rabbit." — which deals especially with this point.

Should do a little quantitative checking out.

11/18/64 p. 385 10°/sec

middle of 385 for on-center unit, discharge occurs as spot approaches the center, moving from the "off" part to the "on" zone of the receptive field. as soon as it crosses the center of the field & moves away from center, the discharge abruptly slows or stops.

In off-center units, the sequence is usually the exact reverse.

Bottom p. 385 deals with concentric-type units, which are different & bear pondering.

summation of E + I accounts for ~~but~~ not for directionally sensitive. ~~black or white spot~~

bottom p. 387 - spont. firing neuron can be suppressed with wrong direction.

11/18/64 Talked with Bill Hagins on the telephone. He recommended that I write Horace Barlow who is now at Berkeley. He did not think there had been much careful thought about dendrites. He thought I should be in closer touch with <sup>expected group</sup>.



11/20/64

68

Here I am again confronted by conflicting priorities, interests & obligations in my research. I have just written Ramon-Moliner re tufted dendrites and Horace Barlow <sup>+ Rosalind + Bill Hopkins</sup> re spatio-temporal patterns, but my first priority should be to finish the work already 3/4 finished. Also, I have to complete something for the Tokyo Congress. For this Congress, my temptation is to discuss spatio-temporal aspects of synaptic inhibition; attempt to summarize the answers to a variety of questions re additivity, effects on EPSP of "conductance" when peripheral, difference between  $I$  pulses &  $I$  background, etc. Other personal priority is to write up the spike model.

The following list was made while in Philadelphia at Nerve as a Fissure conference

1. Basic field paper (Gordon now has a copy of this ditto)
2. Eyre & Jeanne
3. Kinetic spike model
4. Geometric factors
5. Mitral Cell with Gordon (I and II)
6.  $I$  location — see Book 2 degeneracies
7. Tree Generation
8. Aithen story

9. New odd spatio-temporal story re pattern discrimination
10. Also, elaboration of granule cell story
11. Ramon-Moliner & Tufted.

Now look back at p. 1 and p. 5 of Book 4. for older finite dendritic length stuff.

Also Jose & I have been talking about a study group on control theory and non-linear diff. eqns.

low of our own confidence by conflicting priorities  
 interests & objectives in my research. I have  
 just written to you - M. J. has re-fused benefits and  
 those benefits re. extra-temporal patterns, but  
 my first priority should be to finish the work already  
 off finished. Also, I have to complete something for  
 the Tokyo Congress. For this Congress, my intention  
 is to discuss extra-temporal aspects of cognitive activities;  
 attempt to summarize the consensus to a variety of questions  
 re. abstract, effect or esp of "cognitive" when peripheral,  
 influence between of phases & development, etc. Other  
 personal priority is to write up the extra models.  
 The following list was made while in Philadelphia at  
 home on a Friday conference.

1. Basic fact paper (John was in a copy of the book)
2. Exp & frame
3. Kinetic extra model
4. Geometric factors
5. Virtual cell with Jordan (I and II)
6. Facetation - see books by name
7. Tree generation
8. Other story

9. Marshall extra-temporal story re pattern discrimination
10. Also elaboration of grammar cell story
11. Pattern-Matrix & fact

Now I should get p. 1 and p. 2 of Book 1. For other finite activities  
 the fact is that I have been talking about a study group on control  
 theory and non-linear diff. eqns.

11/24/64

69

Frankenhaeuser presented a talk on his frog node experiments and computations done as sequel to those he did with Huxley.

Stimulated me to feel I should write at least a brief note on my model. ~~Two~~ <sup>Three</sup> justifications for simpler model

- (1) Expedite computations where fine points are incidental
- (2) We don't actually know the  $H$  &  $H'$  params for mammalian nerve anyway. Why conditions should one choose? Would that be any less arbitrary than my model? Frankenhaeuser would recommend his frog (vertebrate) data, with a temp. correction.
- (3) Discovery of any deficiencies, re  $H$  &  $H'$  & expt. would provide added insight on whole problem.

Frankenhaeuser's main innovation was that model should respond correctly to current pulses during spike. He also was concerned that current safety factor might be incorrect.

Obviously, a brief presentation would have to touch upon some of these questions.

Now, must return to Fig. 4 of initial paper & consideration of cones & spherical symmetry (cf. pp. 45 + 46 + 34 of this book)

Forbushman presented a talk on his paper made experiment  
and computations done as equal to those he had with  
theory.

Stimulated me to feel I should write at least a brief note  
over my model. ~~Forbushman~~ <sup>Forbushman</sup> ~~presented~~ <sup>presented</sup> for simpler model.  
(1) ~~Specific computations~~ <sup>Specific computations</sup> when his points are misinterpreted  
(2) ~~is not actually known~~ <sup>is not actually known</sup> the H<sub>2</sub> formula for  
numerical values were computed. ~~Why conditions~~  
~~should be chosen?~~ <sup>should be chosen?</sup> ~~Should this be any less~~  
~~existing than my model?~~ <sup>existing than my model?</sup> ~~Forbushman would~~  
~~recommence his paper (abstract) data, with a temp.~~  
~~conversion.~~

(3) ~~Discovery of an epidemic~~ <sup>Discovery of an epidemic</sup>, re H<sub>2</sub> & diff. would  
provide added insight on whole problem.

Forbushman's main reservation was that model should regard  
concepts to current phase being spikes. He also was  
convinced that current spike factor might be incorrect.

Generally, a brief presentation would have to handle  
upper ends of these questions.

How pertinent to the H<sub>2</sub> of initial paper & construction of  
cases differential equation (of H<sub>2</sub> + H<sub>2</sub> + H<sub>2</sub>)  
of this paper



11/25 & 11/27

PERKEL

70

Worked on Mitral Manuscript

Also got off letters to Fender & Gordon Shepard & began one to Perkel

Notes regarding Perkel's Rand Memo - RM-4132-NHT June 1964

A Digital-Computer Model of Nerve Cell Functioning.

11/30/64

on page 8,  $Q$  is quantity of transmitter released

on pp 6 & 7, depletion & restore of reservoir is like Libby & North (appendix

J. Neurophysiol 16 509-527 (1953)

appendix pp 521-525

usage of  $Q$  is inhibitory (naive)

p. 9 incorrect - why use Langmuir absorption isotherm.

Trouble here is that he is using the wrong reference potential. p. 10 indicates awareness that something is wrong, but not what the cause of the trouble is.

~~pp 16-17~~ pp 16-17 discuss shortcomings

p. 37

confuses  $g_i$  with  $g_i$  "charge" of afferent channel  
"charge" delivered to post synaptic membrane

wants rate of removal to be  $g_i l$  from afferent channel  
& says this is to be equated with rate of augmentation of the cell potential ! Pretty fuzzy

Equations (17) and (18) are incorrect

presumably should be  $\frac{dP}{dt} = -\lambda_c P + \sum \lambda_i (g_i/c) e^{-\lambda_i t}$

because then  $c \int_0^{\infty} \lambda_i (g_i/c) e^{-\lambda_i t} dt = g_i$

Label on Michel Manuscript  
 also got off letters to Funder & John Bishop & papers to Funder  
 Notes regarding Funder's Paul Weiss - RM-4132-NH June 1964  
 A Digital Computer Model of Membrane Functioning.

on page 8 of in quantity of transmitter released  
 on p. 7, definition of membrane is like lipid bilayer (apparently)  
 J. Neurophysiol. 16: 259-281 (1953)  
 Appendix pp 251-252

page 8 in manuscript (marked)

p. 9 incorrect - Why was language description contained  
 trouble here is that he is using the wrong reference  
 potential. p. 10 indicates assumption that something is  
 wrong, but not that the cause of the trouble is.

pp 10-11 discuss about coupling  
 p. 37

Professor G: "change" of apparent channel  
 with G: "change" observed to postsynaptic membrane

rate -  
 wants rate of removal to be G<sub>1</sub> from above channel  
 to say this is to be equated with rate of augmentation of  
 the cell potential. ! partly fuzzy

transmission (1) and (2) are incorrect

$$I = G \left( \frac{V - E}{R} \right) e^{-\lambda t}$$

transmission should be  $\frac{dV}{dt} = -R \cdot P + \sum R_i \cdot G_i \cdot e^{-\lambda t}$

because then  $C \left( \frac{dV}{dt} \right) e^{-\lambda t} = G_i$

4/30/64

71

But I would add that for excitation, one should include the factor  $\left(\frac{E_c - V_m}{E_c - E_r}\right) = (1 - v_0)$ , and for inhibition, one should include the factor  $\left(\frac{E_i - V_m}{E_i - E_r}\right) = (\beta - v_0)$

Because, for very brief  $\Delta E$ , my model gives postsynaptic

$$Q/C = (E_c - V_m) \Delta E \Delta t$$

from Ojai  
eq. (1)

~~$$\Delta I_m = \Delta V_m / R$$~~

$$\Delta \{C_m \dot{V}_m - I_m\} = (E_c - V_m) \Delta G_c$$

~~$$Q = (E_c - V_m) \Delta G_c \Delta t$$~~

~~$$\Delta V = (E_c - V_m) G_r \Delta E \Delta t$$~~

$$Q/C = (E_c - V_m) \left(\frac{1}{\tau}\right) \Delta E \Delta t$$

$$= (E_c - V_m) \Delta E \Delta(t/\tau)$$

Also, if  $\frac{Q}{C} = \frac{Q}{C(E_c - E_r)}$ , then

$$Q/C = (1 - v_0) \Delta E \Delta(t/\tau)$$

This can be related to eq. (10) of Ojai paper as follows.

if  $\Delta I = 0 = \Delta \chi$ , and if  $\Delta \dot{V}$  is const for brief  $\Delta t$

$$\text{then } Q/C = \Delta \dot{V} \Delta t = \Delta V$$

$$\hookrightarrow (1 - v_0) \Delta E \frac{\Delta t}{\tau}$$

However, now, to avoid using square pulse or  $\delta$  pulse of current, we

$$\text{try to use the notion that } Q = \int_0^{\infty} I dt = \int_0^{\infty} \lambda_i Q e^{-\lambda_i t} dt = \left[ -Q e^{-\lambda_i t} \right]_0^{\infty} = Q$$

This is equivalent to flow from a neighboring compartment.

But I would not try for excitation, one should include  
the factor  $(\frac{E_c - V_m}{E_c - E_c}) = (1 - v_0)$ , and for inhibition, one  
should include the factor  $(\frac{E_i - V_m}{E_i - E_c}) = (v_0 - 1)$

Because, for very brief  $\Delta t$ , my model gives postsynaptic

~~$\frac{dV}{dt} = \dots$~~

~~$\Delta C_m \ln \dots = (E_c - V_m) \Delta C_e$~~   
 ~~$0 = (E_c - V_m) \Delta C_e \Delta t$~~   
 ~~$0 = (E_c - V_m) \Delta C_e \Delta t$~~   
 ~~$\frac{dV}{dt} = \dots$~~   
 ~~$\frac{dV}{dt} = \dots$~~   
 ~~$\frac{dV}{dt} = \dots$~~

also, if  $\frac{dV}{dt} = \dots$ , then

$\frac{dV}{dt} = (1 - v_0) \Delta C_e \Delta t$

This can be related to eq. (10) of Spike paper as follows.

if  $\Delta t = 0 = \Delta t$ , and if  $\Delta t$  is constant for brief  $\Delta t$   
then  $\frac{dV}{dt} = \Delta v \Delta t = \Delta v$   
 $\frac{dV}{dt} = (1 - v_0) \Delta C_e \Delta t$

However, we, to avoid using square waves or 2 pulses of current, we

try to use the notion that  $Q = \int_{t_0}^{t_1} I dt = \int_{t_0}^{t_1} g_i dE = \int_{t_0}^{t_1} -g_e dE = Q$





This is equivalent to flow from a neighbouring compartment.

12/1/64

Fig 2 (v-v) A but down

But, having noted this much, should try to become explicit about the shortcuts for dendritic model that I have considered before, but not written down. Following points.

- (A) when not at recording site, it may be good enough to have  $\mathcal{E}(t)$  of current which gives instantaneous  $Q$  & hence a sharp voltage change, but <sup>must</sup> have the  $Q$  depend upon  $(1-v_0)$  or  $(\beta-v_0)$
- (B) This works ok when  $\mathcal{E}$  &  $J$  are in same compartment, except that if  $J$  stays on, this has to be included in decay const.
- (C) In other words, must clearly distinguish brief  $\mathcal{E}$  &  $J$  from sustained.
- (D) Furthermore, even when at site, one could avoid abrupt voltage change by backing off from  $\mathcal{E}$  current. One ~~for~~ ~~two~~ possibilities (a) constant current for  $\Delta t$ , (b)  $\Delta i e^{-\Delta t/\tau}$  as incorrectly implied by Perkel, or (c) exact, ~~as~~ a la conductance i.e. proportional to  $(E_c - V_m) \Delta E$ , (d) approx. to this could be done with linear change in  $v$  taken into account i.e. initially have factor  $(1-v_0)$  & change linearly to  $(1-(v_0 + \Delta v))$ .
- (e) However, if we consider possibility that conductance pulse need not be squarely turned off, then (b) looks better again.

Note, for square conductance pulse , current goes , but, if conductance pulse , current goes 

if  $\tau \dot{V} + V = \mathcal{E}(V_c - V)$  has soln  $V \propto e^{-\Delta t/\tau}$   
 what must be the time course of  $\mathcal{E}$  for  $V$  initially zero  
 such that  $\mathcal{E}(V_c - V) \propto e^{-\Delta t/\tau}$

Trouble is we have the product of two variables here

$$V_c \mathcal{L}\{\mathcal{E}\} - \mathcal{L}\{\mathcal{E}V\} \propto \frac{A}{s + \tau^{-1}}$$

$$\therefore V_c (s + \tau^{-1}) \mathcal{L}\{\mathcal{E}\} = (s + \tau^{-1}) \mathcal{L}\{\mathcal{E}V\} + A$$

note that  $A \propto Q(V_E - V_0)$  see p. 76

12/1/64

we have

$$\tau \dot{V} + V = \epsilon(V_E - V) = A e^{-\lambda t}$$

here  $A$  has dimension of voltage

for  $V(0) = 0$ , our pair give  $\bar{V}(s+\tau) = \frac{A}{s+\lambda}$

$$\bar{V} = \frac{A}{(s+\lambda)(s+\tau)}$$

add  $V_0 e^{-t/\tau}$  for nonzero I.C.

$$\therefore V(t) = \frac{A}{\lambda - 1/\tau} (e^{-t/\tau} - e^{-\lambda t})$$

Now, we can solve for  $\epsilon$

$$\begin{aligned} \epsilon &= \frac{A e^{-\lambda t}}{V_E - V} = \frac{e^{-\lambda t}}{(V_E/A) - \left( \frac{e^{-t/\tau} - e^{-\lambda t}}{\lambda - 1/\tau} \right) - \frac{V_0}{A} e^{-t/\tau}} \\ &= \frac{A}{V_E e^{\lambda t} + \frac{A}{\lambda - 1/\tau} (1 - e^{(\lambda - 1/\tau)t})} = \frac{A e^{-\lambda t} (\lambda - 1/\tau)}{V_E (\lambda - 1/\tau) + A (e^{-t/\tau} - e^{-\lambda t})} \end{aligned}$$

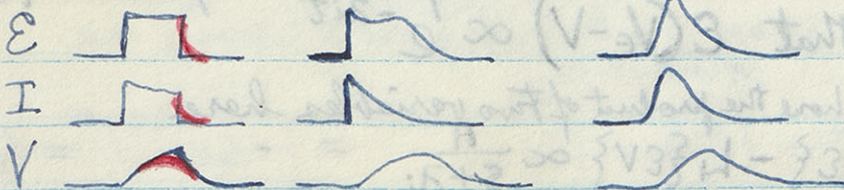
see p. 76

Not hard to plot  $e^{-\lambda t} \propto$

$V \propto$

$V_E - V \propto$

$\epsilon \propto$  hump due to in denom.



See p. 76

12/1/64

73

To have  $\mathcal{E}(V_E - V) = A e^{-at}$   
 One can get a solution of the following kind  
 Don't yet know anything about uniqueness

Suppose  $\mathcal{E} = B e^{-at} + F(t)$

$$\mathcal{E} V_E = B V_E e^{-at} + V_E F(t)$$

~~and  $\mathcal{E} V = \mathcal{E} V$~~   
 above can be satisfied if

$$\mathcal{E} V = (A + B V_E) e^{-at} + V_E F(t)$$

$$\text{and } V = \frac{\mathcal{E} V}{\mathcal{E}} = \frac{(B V_E - A) e^{-at} + V_E F(t)}{B e^{-at} + F(t)}$$

But we know that  $V = \frac{A}{\lambda - 1/\tau} (e^{-t/\tau} - e^{-at})$

So that we could <sup>try to</sup> solve the above for  $F(t)$  ?

Note from eq (10) of my Ojai paper, for small  $\Delta t$  and with  $\Delta \mathcal{J} = 0 = \Delta \Psi$

$$\text{get } \Delta v \approx \dot{v} \Delta t = (\dot{v})_0 \Delta t + (\Delta \dot{v})_0 \Delta t$$

$$= -\mu \Delta t (v_0 - v_s) + (1 - v_0) \Delta \mathcal{E} \Delta t / \tau$$

↓ this term is zero if  $v_0 = v_s$

$$\text{But otherwise get } -\Delta t \left\{ \frac{v_0}{\tau^*} - \frac{\mathcal{E}_0}{\tau} \right\} = \frac{(v_0 - v_{s0}) (\Delta t)}{\tau^*}$$

$$\text{where } \tau^* = \frac{\tau}{1 + \mathcal{E} \tau}$$

in other words, this is the rate of previous approach to  $v_{s0}$

ET 12/1/64

$E(V_e - V) = A \cdot C$

Don't get wrong...  
The amount of...  
Don't get wrong...

~~$E = B \cdot C + F(t)$~~

~~$E = B \cdot C + V_e F(t)$~~

~~$E V = (A + B \cdot C) \cdot C + V_e F(t) \cdot C$~~

~~$\frac{E V}{C} = \frac{(A + B \cdot C) \cdot C + V_e F(t) \cdot C}{C} = A + B \cdot C + V_e F(t)$~~

~~$\frac{E V}{C} = A + B \cdot C + V_e F(t)$~~

~~Not had to get...  
So that we can...  
But we know that...~~

Note from (10) of my paper...  
 $\Delta V = 0 = \Delta A + \Delta C$

$\Delta V = \Delta A + \Delta C = 0$

hump due to... in denom.

$\Delta A = -\Delta C$

Minimum is...  
 $\Delta A = -\Delta C$

$\frac{\Delta A}{A} = -\frac{\Delta C}{C}$

When  $\Delta C = 0$ ...



12/2/64

74

As usual, I am torn between several projects & at the moment, have spinning in my head, titles & opening paragraphs for four different projects, not to mention the Mitral Cell paper.

① for Physiol Congress Abstract

"Potency of Synaptic Inhibition"

could be short title, and then go on to say that will discuss factors which determine potency in various soma-dendritic spatio-temporal patterns of synaptic activity.

② Ramon-Moliner will be in town today. Note with him could begin. Title - Significance of Dendritic Tufts of Secondary Afferent Nerve.  
"We begin with the colorful remark that the dendritic tufts help these neurons play a pre-amplifier role. X Introduce pre-amplifier word as suggestive or provocative, but add that the analogy is not meant to be carried too far."

③ The interdependence of  $E, I, V$  on pp 72 & 73

Could, of course, choose to make  $E$  have a gradual onset, but there is not too much point in this. Also, note that this type of  $I$  comes from neighboring cpts. anyhow; actually, in general, should let  $E \& I \& V$  be like sums of exponentials with different delays, but then can crudely approx by  $I \propto e^{-\lambda t}$  where  $\lambda$  takes care of smear & initial delay is taken care of separately. Question is, how fully can these simplifications be made consistent with whole.

is. question of valid short cuts.

④ Thoughts about action potential model paper (over)

Answer given in following paragraphs; but first make two  
 comments. The model to be presented here ~~has many parts~~  
 belongs to the family of models that has been discussed  
 by FitzHugh. &

(over)

12/2/64

75

Possible title:

## "A Simpler Mathematical Nerve Action Potential Model"

It seems best to begin this paper by asking, and answering the following question: why bother with alternative mathematical models of nerve action potentials when the Hodgkin-Huxley model has proved so successful? My answer is that a simpler

← model can have advantages for certain purposes, such as the following: ~~(1) ~~It is a simpler model may permit a very great saving in~~~~ (1) There are many problems ~~involving~~ related to non-soma-dendritic geometry and problems related to networks of neurons which are sufficiently complicated ~~that~~ to justify the significant reduction in computation time that can be achieved by a simpler model; (2) Provided that the simpler model is qualitatively and even semi-quantitatively in agreement with the more complicated model, it ~~is~~ <sup>merits</sup> consideration as a tool in the investigation ~~of problems~~ of tissues whose Hodgkin-Huxley parameters have not been determined (because then it is only qual or semi-quant <sup>also</sup>).

(3) In the sense of the class of models discussed by Fitzhugh, we may gain considerable insight from ~~the~~ comparisons of the adequacy of these models in various tests: it provides a way of distinguishing what is most essential from what may be accidental, special, or even misleading.

Actually, in paper, it may be desirable to have a brief paragraph on each of the above; each with appropriate subtitle. See also p. 69 of this notebook.

0.1	0.02	0.102
0.2	0.04	0.204
0.3	0.06	0.306
0.4	0.08	0.408
0.5	0.10	0.510
0.6	0.12	0.612
0.7	0.14	0.714
0.8	0.16	0.816
0.9	0.18	0.918
1.0	0.20	1.020
1.1	0.22	1.122
1.2	0.24	1.224
1.3	0.26	1.326
1.4	0.28	1.428
1.5	0.30	1.530
1.6	0.32	1.632
1.7	0.34	1.734
1.8	0.36	1.836
1.9	0.38	1.938
2.0	0.40	2.040
2.1	0.42	2.142
2.2	0.44	2.244
2.3	0.46	2.346
2.4	0.48	2.448
2.5	0.50	2.550
2.6	0.52	2.652
2.7	0.54	2.754
2.8	0.56	2.856
2.9	0.58	2.958
3.0	0.60	3.060
3.1	0.62	3.162
3.2	0.64	3.264
3.3	0.66	3.366
3.4	0.68	3.468
3.5	0.70	3.570
3.6	0.72	3.672
3.7	0.74	3.774
3.8	0.76	3.876
3.9	0.78	3.978
4.0	0.80	4.080
4.1	0.82	4.182
4.2	0.84	4.284
4.3	0.86	4.386
4.4	0.88	4.488
4.5	0.90	4.590
4.6	0.92	4.692
4.7	0.94	4.794
4.8	0.96	4.896
4.9	0.98	4.998
5.0	1.00	5.100

where  $T_x$  represents trigger or transmitter quantity or something equivalent and  $\lambda$  is needed to normalize;  $\lambda e^{-\lambda t}$

12/2/64

$$\tau \dot{V} + V = A e^{-\lambda t}$$

$$V = A \left( \frac{e^{-\lambda t} - e^{-\tau t}}{\lambda - \tau} \right)$$

for  $V(0) = 0$

let  $\tau = 5 \text{ msec}$  and  $\lambda = \frac{10}{\tau} = 2 \text{ msec}^{-1}$

for  $V(0) = 0$   
 $A = 1 * V_e$

$$\text{and } \mathcal{E} = \frac{e^{-\lambda t}}{\left( \frac{V_e}{A} \right) - \left( \frac{e^{-\tau t} - e^{-\lambda t}}{\lambda - \tau} \right)}$$

$t_{\text{msec}}$	$e^{-\lambda t}$	$e^{-\tau t}$	$e^{-\tau t} - e^{-\lambda t}$	$\frac{e^{-\tau t} - e^{-\lambda t}}{1.8}$	$1 - \text{this}$	$\mathcal{E}$
.1	.9802	.8187	.1615	.0898	.91	1.08
.2	.9608	.6703	.2905	.1614	.84	1.145
.3	.9418	.5488	.3930	.218	.782	1.205
.4	.9231	.4493	.4738	.263	.737	
.5	.9048	.3679	.5369	.298	.702	1.29
.6	.8869	.3012	.5857	.325	.675	
.7	.8694	.2466	.6228	.346	.654	
.8	.8521	.2019	.6502	.361	.639	1.33
.9	.8353	.1653	.6700	.372	.628	
1.0	.8187	.1353	.6834	.380	.620	1.32
1.5	.7408	.0498	.6910	.384	.616	1.2
2.0	.6703	.0183	.6520	.362	.638	1.05
2.5	.6065	.0067	.5998			
3.0	.5488	.0025	.5463			
4.0	.4493	.0003	.4490	.25	.75	.60
5.0	.3679					
.1				.055	.945	.105

where  $\tau$  represents trigger or transmitter quantity or something equivalent  
 and  $\lambda$  is needed to normalize;  $\lambda e^{-\lambda t}$

12/2/64 Today José had visitor, Dr. Joel Brenner, mathematician now at Stanford Research. He is translator of Gantmacher & other important Russian books & very widely able mathematician. 76

I presented something on membrane models and also the degeneracies in the middle of Book 2. May 1963 —

See exp. 6/25/63 731,300 series

Summary 7/10/63

Dr. Brenner said that there is a paper by COLLAR in Q.J. Math. (62 or 63) prob can be located in Math. Reviews with title "On Cross-Symmetric Matrices" which may bear upon these degeneracies.

He thought this was worth writing up to bring out the various points.

---

To complete page 73, note that  $A \propto (V_e - V_0)$

Then  $V = V_0 e^{-t/\tau} + A \left( \frac{e^{-t/\tau} - e^{-\lambda t}}{\lambda - 1/\tau} \right)$  and that, in general,  $V_0 \neq 0$

$$\text{and } E = \frac{e^{-\lambda t}}{\left( \frac{V_e - V_0 e^{-t/\tau}}{A} \right) + \left( \frac{e^{-t/\tau} - e^{-\lambda t}}{\lambda - 1/\tau} \right)}$$

And if we set  $A = B \left( \frac{V_e - V_0}{V_e} \right)$ , we get the result

$$E = \frac{e^{-\lambda t}}{\frac{V_e}{B} \left( \frac{V_e - V_0 e^{-t/\tau}}{V_e - V_0} \right) + \left( \frac{e^{-t/\tau} - e^{-\lambda t}}{\lambda - 1/\tau} \right)}$$

where  $B \propto \lambda \tau$  and has dimensions of voltage (see opposite page)

12/1/64 Today after lunch with Dr. Joel Brenner, mathematician from  
 of State University. He is translator of French and other important papers  
 books & very widely able mathematician.

Presented some notes on various models and also the exercises  
 in the middle of Book 2. May 1963

Summary 7/10/63  
 Sec 2. 6/27/63  
 131.300

Dr. Brenner said that there is a paper by GOLLAR in  
 Q. J. Math. (1953) that can be located in Math Review  
 with title "On Cross-Symmetric Matrices"  
 (Such may bear upon these exercises.)

He thought this was worth writing up to keep out the various  
 prints.

To complete page 13, note that  $A \in (V_0/V_0)$   
 and that in general,  $V_0 \neq 0$

$$V = V_0 + A \left( \frac{V_0 - V_0}{V_0 - V_0} \right)$$

$$\text{and } E = \left( \frac{V_0 - V_0}{A} \right) + \left( \frac{V_0 - V_0}{V_0 - V_0} \right)$$

and if we set  $A = B \left( \frac{V_0 - V_0}{V_0} \right)$ , we get the result

$$E = \left( \frac{V_0 - V_0}{B} \right) + \left( \frac{V_0 - V_0}{V_0 - V_0} \right)$$

Box 27 and the description of matrices (complete page)

12/3/64

77

Resolved on Explicit Strategy for getting papers written & reducing the nagging backlog.

\* Devote every A.M. completely to writing. Avoid all distractions, such as mail, telephone, conversation and defer these ~~to~~ the afternoon. Stay home if necessary to establish this routine. This A.M. regime should be devoted to one paper at a time. ~~concentrate~~ Recall the advice of Terrell Hill.

Note also that Dick Podolsky told me the other day that he had asked A.V. Hill whether writing had become any easier for him over the years. The answer was no, he still has to go through 7 or 8 drafts; his only advantage over a neophyte is that he knows it will be hard work from the outset & presumably, thus avoids some of the confusion & discouragement of the neophyte.

Just for the hell of it, could call this new resolve, project backlog,  $\equiv$  GOLKCARB, and try to tick off the papers as they are produced. If bright ideas come for other papers etc., as distractions, ~~defer~~ <sup>defer</sup> them ~~to~~ to the afternoon, but reserve the AM for the particular paper in process.

As of now. Should work first on Mitral paper (also computations figures can be left to afternoons, or deferred, but text must be pressed forward). Then perhaps impulse <sup>most papers</sup> model next, and then <sup>basic</sup> potential paper next, based on what I already have.

My usual procedures are fine for advancing several investigations, but not so good for writing.



Now on ditto

Title page

p.1.1 <sup>recording</sup> ~~The~~ Experimental ~~Situation~~.

p.1.2+3 fine print re Fig. 1-B collaterals etc.

\* maybe pull last sentence of p.1.3 out of fine print.

p.2.1 The experimental records.

p.3.1 Response characteristics at three depths in two periods.

p.4.1 Spherical symmetry and synchrony.

p.4.1.1 - exp. factors re. symmetry & synchrony to insert.  
(but perhaps defer until later)

p.4.2 details on core  $\Omega$  etc., then  
Flow of current confined within cones.

p.4.3 Spherical equipotential contours and radial current  
(perhaps should read isopotential surfaces)

p.4.4 gives equations (1) & (2)

p.4.5 Puncture of spherical symmetry: external current path.

→ The Neurophysiological Records to be Analyzed

Presentation of The Neurophysiological Problem

→ ~~Part I~~ Description of Data to be Analyzed

→ Part II Theoretical Significance of <sup>Punctured</sup> Geometric Symmetry.

12/4/64

Yesterday completed several pages of initial paper & also prepared ink drawing of Fig. 4-A; may wish to improve arrows for current & then photograph & modify for puncture. Also put dashed lines into Fig. 3. Where do we stand now?

Completed up through cones, but not puncture and external current. The last page of ditto might as well be retyped to modify and cleanup.

Perhaps overall heading of this <sup>Division</sup> section should be

## GEOMETRIC

Theoretical  
Sig.

## CONSEQUENCES OF GEOMETRIC SYMMETRY

Theoretical Significance of Symmetry and Puncture.

to separate from earlier expt. sections.

Next section perhaps entitled Punctured Sphere: External Path

done today

Next ~~the~~ section: Potential divider effect, wrote 12/7/64

Question: Should middle of p. 4.3 to middle p. 4.5 be deferred to an appendix to be treated with resistances?

Vector calculus and geometry  
 of the 3D space. The  
 geometry of the 3D space is  
 described by the metric tensor  
 and the Levi-Civita symbol.

The metric tensor is a symmetric  
 bilinear form on the tangent space.

The Levi-Civita symbol is a  
 completely antisymmetric tensor.

The divergence of a vector field is  
 defined as the trace of the covariant derivative.

The curl of a vector field is  
 defined as the exterior derivative of the corresponding 1-form.

The divergence of a tensor field is  
 defined as the trace of the covariant derivative.

The divergence of a tensor field is  
 defined as the trace of the covariant derivative.

The divergence of a tensor field is  
 defined as the trace of the covariant derivative.

The divergence of a tensor field is  
 defined as the trace of the covariant derivative.

12/2/64

Wrote up potential divider effect; perhaps also Shunt Current Effect

79

Telephone call - Greutzfeldt is in town. He + Dieter Lux are to see me this afternoon

Looking at Gordon's draft, have now replaced all of his section 4, except the part which (a) refers to cylinders inside cone, which may better go into figure legend. (b) instead of time which I have already deleted twice, and which should come at end of this section, now, altogether. (4.4) has been improved upon. It may prove possible to present (b) together with Fig. 4c and Fig. 5.

Possibly here, ready for new Division, i.e.

Part III - Response <sup>Deduced for</sup> Contribution by Mitral <sup>Bodies</sup> ~~Soma~~ and Dendrites.

\* Talked with Greutzfeldt, Lux & Klee.

They study cat cortex & are correlating intracellular records with surface leads during EEG spindles & strychnine convulsions.

Seems to be a good correlation between intracellular (somatic) epsp & spikes & surface positivity, fitting idea of extracell. current from dendrites to soma. They were puzzled by sharp surface (+, -) when intracellular spiking was severe, I was able to point out that after pos. probably causes this. This apparently was a new idea to them. Note: they are not dealing with unitary epsp but with bursts epsp & bursts of spikes, hence after pos. is multiple.

What is the effect of ...

Telephone call - ...

Looking at ...

Probably ...

Part III - ...

\* ...

seems to be a ...

12/8/64

Mitral Paper - start to write part III, or last of part II

Introduction

Part I - Electrophysiological Records to be <sup>interpreted</sup> Analyzed

Part II - Theoretical Significance of Punctured Symmetry

Part III - Response <sup>Computed</sup> ~~Derived~~ for Mitral Bodies and Dendrites  
(Figs 5 & 6)

Part IV - Latencies and Gradients <sup>Computed</sup> ~~Derived~~ for Mitral Model  
Figs 7 & 8

maybe split <sup>Part IV</sup> Latencies with Distance  
<sup>Part IV</sup> Radial Gradients of Potential

Part V - Discussion & Reconstruction

at transition from II to III, may need to point out what is hypothesis! Also, may need outline of computation

Picked up photography today - Jordan's expt. series  
Also Superposition figure.  
Left to be done - redo Fig. 3 with dashed lines  
planar radial symmetry diagram

Virtual Paper - start to write part II, or part II of part I

Part I - Laboratory/physical records to be analyzed  
Part II - Theoretical significance of fundamental symmetry  
Part III - Reference material for Virtual Paper and Database

Part IV - Exercises and questions related to Virtual Model  
(Page 240)

Part IV - Exercises with solutions  
Part IV - Radical Products of Potential

Part V - Discussion & Presentation

of transition from II to III, may need to point out  
(what is 'input series'! Also, may need outline of computation

Parted up photographs today - photos with series  
Also superposition figures  
left to be done - photos 3 with dashed lines  
show radial symmetry diagram

12/8/64

Think about Cal. Tech lectures for Mar. 8 & 9, as just confirmed by Fender. He requests titles, abstracts & reprints or class notes.

Simplest to do as implied by correspondence

I overview of dendritic studies

II details

(Did not finish - Appointment with Dentist.



for  $TK = 0.01$

$\tau = 1$

.9041   .4772   .0963   .0400   .2036   .2324   .2884 (7)

.9141   .5272   .1018   .0446   .2134   .2236   .2841 (9)

.9241   .5083   .0987   .0334   .1554   .1816   .2800 (9)

for  $TK = 0.05$

.9041   <sup>peak</sup> .9431   .5861   .3082   .3003   .2754   .2658 (7)

.9141   <sup>post peak</sup> .9343   .6438   .3309   .2975   .2840   .2664 (9)

.9241   <sup>post peak</sup> .9372   .6031   .2889   .2559   .2460   .2452 (9)

In second two cases, spike in  $gt. 1$  develops a little faster to a slightly smaller peak

.9041   spike in (4) is at  $KT = 16$     $TK = .15$     $ampl = .8115$

.9141   83   .164 later   .7938 smaller

.9142   72   .142 earlier   .8918 larger

$\therefore$  in 9141, dendrites are definitely more shunt worthy

in 9241, having  $USD = 200 + UD = 400$  makes as though dendritic capacity is reduced rel to soma,

See over

as though  $N$  halved.

12/14/64

The writing regime broke down last week, partly because of insufficient sleep Mon. night & because of dental marathon on Wednesday. Did not succeed in completing pages (after two last Monday) but did succeed in roughing out next part & thinking about outline. To work, the regime may need to have one week rigidly on routine, followed by a week less rigid gestation & then back again, but in any case, mornings largely devoted to writing or matters very closely related to writing.

12/14/64 Afternoon - plan recheck of WXR 796C which had trouble when first checked (11/17/64)

Something did not work between main prog & subroutines, conceivably, due to new args etc.

First, recheck the programs of (11/9/64) for obvious error

Not obvious

∴ setup with 64796.1201

NT=6, NSTEP=2

IFTEST=81

60

IFAB = 0

Also, refer back to pp. 63 + 65

64795-9241 + 9244 did not work out as expected.

Must now carefully compare 9041, 9141, 9241

		<sup>25</sup> UA	<sup>100</sup> UD	<sup>2.5</sup> USA	<sup>100</sup> USD
9045	10 dendrite originally				
9041	Dendrite's gts	25	100	5	200
9141	10 " "	25	400	5	400
9241	10 " "	25	400	5	200

Assuming  $R_m$  the same for axon, soma, dendrites

$$\frac{USD}{USA} = N \frac{GD}{GA} = N \left( \frac{DD}{DA} \right)^2 \left( \frac{LA}{LD} \right)$$

To change USD without any other change, corresponds to a change in  $N$ . (e.g. 9241)

$$LD = LA = 0.04 \text{ mm} \quad \text{---} \quad \text{---} \\ = 40 \mu$$

$$LD = LA = 0.08 \text{ mm} \\ = 80 \mu$$

$\frac{USA}{UA}$  changed from  $\frac{1}{10}$  to  $\frac{1}{5}$

$\frac{USD}{UD}$  = - - - 1 to 2

12/15/64

83

Take a fresh look at .9041 + .9142

Conclusion is that discrepancy is probably attributable to the difference in fineness of lumping.

First compare 9045 and 9041

In 9045 have  $NJD = 10$  with  $\Delta Z_D = 0.1$ , i.e.  $UD = 100$   
 $\Delta Z_A = 0.2$ , i.e.  $UA = 25$

Now, we want the total dendritic length to be  $Z_L = 0.5$   
 instead of  $Z_L = 1.0$

Suppose we quadruple all  $R_m$  (axonal, somatic, dendritic) to achieve this, leaving all diameters unchanged.

note that  $UA + UD$  consp to  $\mu\epsilon \propto (\Delta Z)^{-2} \propto R_m \frac{d}{L^2}$

Clearly, if all diameters and lengths unchanged, then all  $\mu\epsilon$  must be quadrupled.

	UA	UD	USA	USD	UD/UA	USD/USA
9045	25	100	2.5	100	4	40
hypoth.	100	400	10	400	4	40

← But now, if we double all lengths, so that there are only 5 dendritic cpts., then  $UA + UD$  are reduced by a factor of four (because of  $\frac{1}{L^2}$  above, or alternatively because both core  $G$  doubled and membrane  $C$  halved), whereas  $USA$  and  $USD$  are only halved, because capacity of soma remains unchanged. This gives (9041)

25	100	5	200	4	40
----	-----	---	-----	---	----

$\Delta A = 0.5$  in.  $VA = 22$   
 $\Delta A = 0.1$  in.  $VA = 100$   
 $\Delta A = 0.01$  in.  $VA = 1000$

Now, we want the total number of bits to be  $2^N = 0.5$   
 $2^N = 1.0$   
 Suppose we quadruple all  $R_{ij}$  (and double  $\Delta A$ )  
 to achieve this, leaving all distances unchanged.  
 Note that  $VA + VD$  comp to  $4 \times (\Delta A) \times R_{ij}$  or  $R_{ij}$  of  $\frac{1}{4}$

(Note: all distances and lengths unchanged, then  
 all  $R_{ij}$  must be quadrupled.)

100	100	100	100	100	100
100	100	100	100	100	100
100	100	100	100	100	100
100	100	100	100	100	100

But now, just double all lengths, so that there are  
 only 256 bits total. Then  $VA + VD$  is reduced to  
 a factor of 4 (because of the change in the  
 distances between the nodes).

# Viewly

Set up rerun of 9041 with  $DT = 0.002$   
 and 9341 with  $USA = 5.5$

12/15/64

84

One could decide to leave LA at 80 $\mu$   
but halve LD back down to 40 $\mu$   
~~as~~ increasing NTD from 5 to 10  
This takes us from 9041 to 9141

UA	UD	USA	USD	$\frac{UD}{UA}$	$\frac{USD}{USA}$
25	400	5	400	16	80

which should be OK, except for lumping discrepancy.

---

Alternatively, suppose we changed only Rm  
of soma and dendrites, but not axon.

Then starting from 9045, would get

UA	UD	USA	USD
25	400	10	400

where LA and LD would still be 40 $\mu$  & NTD=10

And now, if we double LA to 80 $\mu$ , but leave LD  
unchanged, we ~~get~~ halve USA and quarter UA

UA	UD	USA	USD
6.25	400	5	400

which differs from 9141 only by factor of 4 in UA

But this is not what is sought either

---

to improve 9141, could fiddle UA or USA or  
both to try to make soma spike a little earlier and  
larger. Could try just USA = 5.5 or 6.

One could think to have LA at 800  
but value of LA is 1000  
minimum USD from 5 to 10

This takes us from PCH1 to PCH2

1/21	1/21	USD	USD	UD	UA
80	10	100	2	100	22

What would be OK for buying something

Alternatively, suppose we changed only PCH  
of some and double it, but not order.

The other way round, would not

UD	UD	UD	UD
100	10	100	22

When LA=10, PCH1 would be 100

What if we double LA to 800, but leave PCH  
unchanged, we get value UA and order UA

UA	UD	UD
22	100	2

What if we double PCH1 and keep LA UA  
but the value of LA is 1000

to improve PCH1, we need to have UA=1000  
with the same value of LA=1000  
order. Cost of UA=1000

12/15/64

85

setup 64795.9410  
9411

where 9410 is same as 9041 except that  $IFVE = 0$   
and that  $DT = 0.002$   
 $NT = 115$

~~this is to~~

$NSTEP = 5$   ~~$NSTEP = 2.5$~~  per .001

whereas 9041 was 1 per .001

∴ this will check adequacy of  
step size in 9041 and provide  
more detailed DT to compare  
with 9141 and 9411  
old new

9411 is similar to 9141 except that  $USA = 5.1$   
as a fudge to try to improve  
over 9141 to fit 9041

also putting in 64796.1201 sep. 82

as more detailed test of WXR796C

filed & then phoned Moura Hammond & learned  
that EQUIVALENCE must not be used for  
dummy variables of subroutine argument. Thus  
I must delete EQUIVALENCE and restore carefully  
matched but non-identical arguments.



step 1	PII
step 2	PII

PII is same as P041 except that  $FVE = 0$   
 and that  $DT = 0.002$   
 $NT = 112$

step 2 ~~PII~~ 2.2 per 1001  
 from P041 was 1 per 1001

∴ This will create redundancy of  
 step 2 in P041 and provide  
 more detailed DT to compare  
 with P111 and P112  
 new

PII is similar to P111 except that  $USA = 2.1$   
 as a way to test to improve  
 over P111 to P041

One thing in LA 796.1201 sep. 82

as mentioned in WRRPDC

that EQUINANCE must not be used for  
 human variables of subjective responses. This  
 must be EQUINANCE and better carefully  
 checked but not technical arguments.

12/17/64

86

Paused to reflect. Also, read symposium on  
Science & Public Policy (Fed Proc. 23 (#6 Part I) 1964  
1267-1284

Handler, Weinberg, Fountain, Finer

Mutual dependence of Research, Univ. & Govt. is a fact & problem is  
how policies & conditions be appraised for future. Report to Natl. Acad.  
"to enunciate the principles and philosophy which can serve as a basic  
policy in the future conduct and administration of federal programs  
in support of fundamental research" The committee COSPUP  
chose to restrict <sup>consideration</sup> to support of fundamental research in Universities.

Concluded that grant program should remain backbone of support.  
Criterion must continue to be scientific merit. (for basic research)  
Essential to use scientific panels for this.  
Avoid problems to diversion from old research to new research  
by dropping proposals more carefully and more broadly.  
Other types of support can be used to support weak units  
or bolster certain geographic areas, or improve scientists

Responsibilities of Scientists for success of grants program

- (1) conscientious effort to achieve stated purpose of grant  
(no other right to the funds)
- (2) serve conscientiously & willingly on study sections
- (3) obligation to Univ. Community to help with teaching as  
well as research

1964 (1964) Science & Public Policy (Fall/Winter, 23 (1964))  
1964-1965

Handley, Blumenthal, Fountain, Finer

Historical perspective of research, but v. of past in effect + program in  
long-term of continuation be applied for future. Part to that end.  
to summarize the principles and philosophy. which can serve as a basis  
policy in the future conduct and administration of federal programs  
in support of fundamental research. The committee COSPUP  
has to report to support of fundamental research in the 1960s.

Concluded that great program would remain boldness program  
interior must continue to be scientific merit. (Some would  
be required to use scientific panels for this.  
local problems to discussion from old research to new research  
big drafting proposals were carefully and meticulously  
over time support or be used to support work with  
of which, certain geographic areas, or express certain

- participation of scientists for success of great program
- (1) continuation of effort to achieve total program of great  
(no other way to the future)
  - (2) some commission + authority in study certain
  - (3) obligation to have, authority to support, funding or  
well-being

12/17/64

.9410 agrees perfectly with .9041

DT = .01 ~~0.01~~

DT = .001

NJD = 5

Now can compare with

9141

USA = 5.

currently both have NJD = 10

9411

USA = 5.1

Peaks	9410		9141		9411	
Cpt.	KT	ampl	KT	ampl	KT	ampl
1	25	.9447	23	.9409	24	.9407
2	38	.9526	37	.9522	38	.9497
3	47	.9449	46	.9430	48	.9435
4	77	.8128	83	.7938	72	.8917
5	(5) 84	.6653	86	.7202	75	.7897
6			90	.6587	78	.7065
7	(6) 91	.5645	94	.6079	82	.6387
8			97	.5674	85	.5849
9	(7) 100	.5032	102	.5366	89	.5437
10			107	.5152	93	.5146
11	(8) 108,9	.4757	112	.5018	97	.4964
12			115	.4945	101	.4867
13	(9) 111 <sup>2+</sup>	.4674	118	.4909	104	.4823
14			119	.4895	105	.4809

WXR 611C treated with ...

WXR 757C treated with ...

**Save**

**Delete**

- WXR 795C
- 93C
- 94C
- 95C
- 82C
- WXR 751C
- WXR 791C
- 91C
- 92C

- Branching extrop
- WXR 611C
- WXR 606C
- WXR 69C

Save

- 706C
- 707C
- 709C

delete  
12/22/64

- 603
- 604
- 605C

delete  
12/22/64

- 76
- 77
- 781
- 783
- 785
- 78

delete  
12/22/64

- 79
- 80
- 81
- 83
- 84
- 85
- 86

12/21/64

Call from Brunelle to delete superseded programs and subroutines from his BRT.

Currently using WXR 795C <sup>Developed for initial cell problem.</sup> master for axon-soma-dendrite with WXR 93C, 94C, 95C and 82C  
Rungkutta      Ve      plot

Not successful WXR 796C with 96C & 97C, 95 & 82 because of Equivalence of dummy arguments.

8/5/63

The compartmental series began with WXR 701C, 71, 72, 73

See Book 3

703 & 706 straight chain  
707 & 709

780, 781, 783, 785, 786 ~~soma-dendrite axon-soma-dendrite~~

WXR 791C worked well & produced grandaddy series 91C, 92C, 82C

WXR 793C with 93 & 94C introduced 4th power  
see pp 15-29 of Book 4

WXR 611C treated subpopulations of Aitken's neurons.  
pp 19 and 24 of Book 4

Previous one is 606

WXR 751C kinetics of my spine system.

Marshall 12/29/64, to ...  
with grand ...

10/1/04

Call from Bureau to check supervised programs  
and subventions from this BRT

Currently using WKR 755C  
with WKR 93C, 95C and 83C

Not successful WKR 755C with 95C & 97C  
because of performance of drawing application

The computerized central register with WKR 701C, 71, 72, 73

180, 781, 783, 787, 788  
787

WKR 751C worked well + produced probably series  
91C, 92C, 83C

WKR 935C with 93C introduced after power  
on 11/12 - 21 of book

WKR 611C tested subventions of Wilson's names  
11/12 on 11/12 of book

WKR 752C printer and application

12/23/64 Heavy head cold today. Mild toothache & fatigue yesterday. Presumably much of depressed state of past few weeks has been related to low level toothache and virus. It has happened to me before in December. Obviously cannot rise to any heights of creative writing, but might be able to go over the computer programs that were on BRT that Brunelle called about.

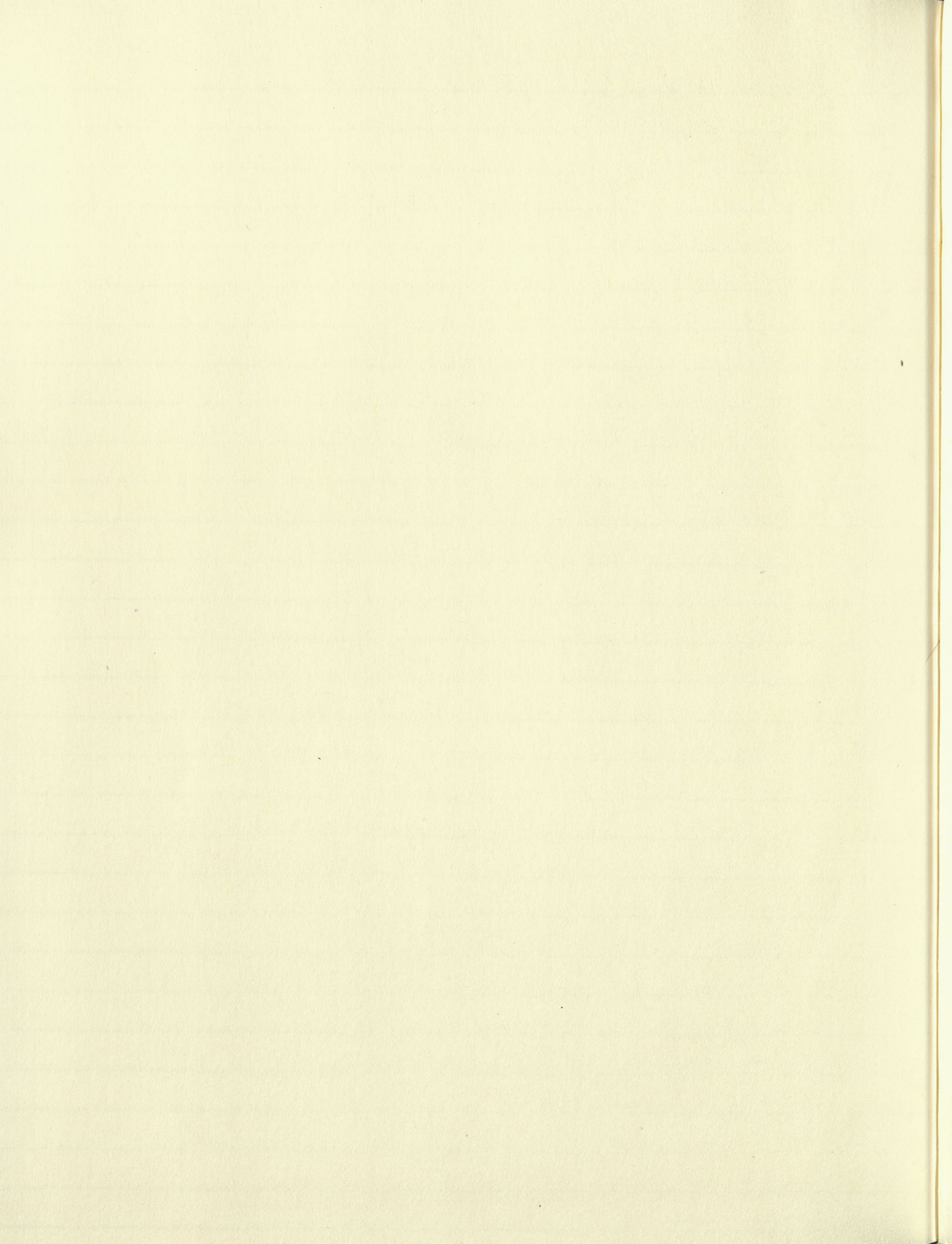
12/24/64 Also talked with Kandel & with Phil Nelson about their anomalous rectification & the effect of  $R_m$  or  $G_j$  change upon rate of rise of EPSP. Wrote letter to Kandel.

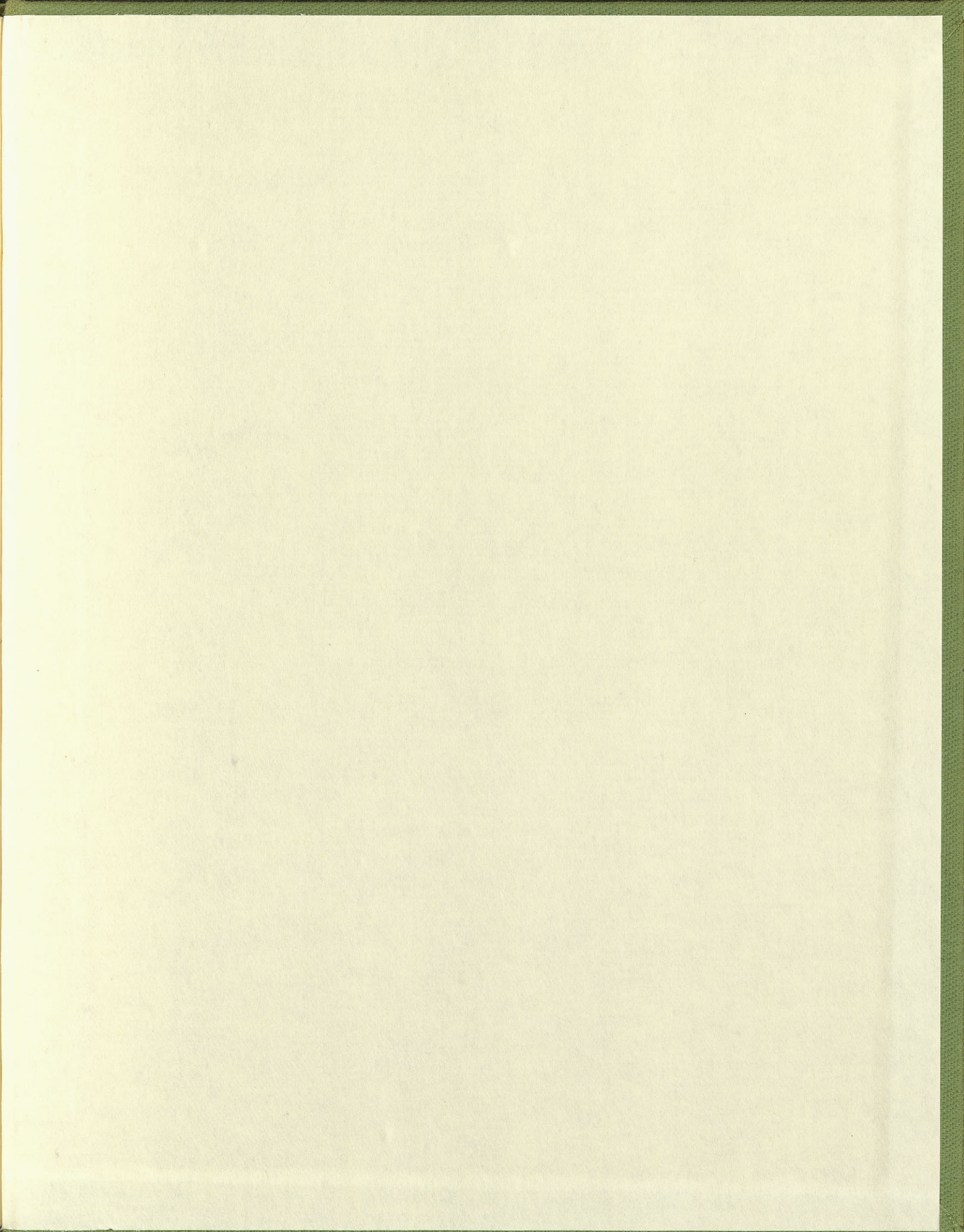
12/28 Talked with Phil also about comparing notes with Van Buren on the matter of + and neg amplitudes re: ~~re~~ additivity of units.

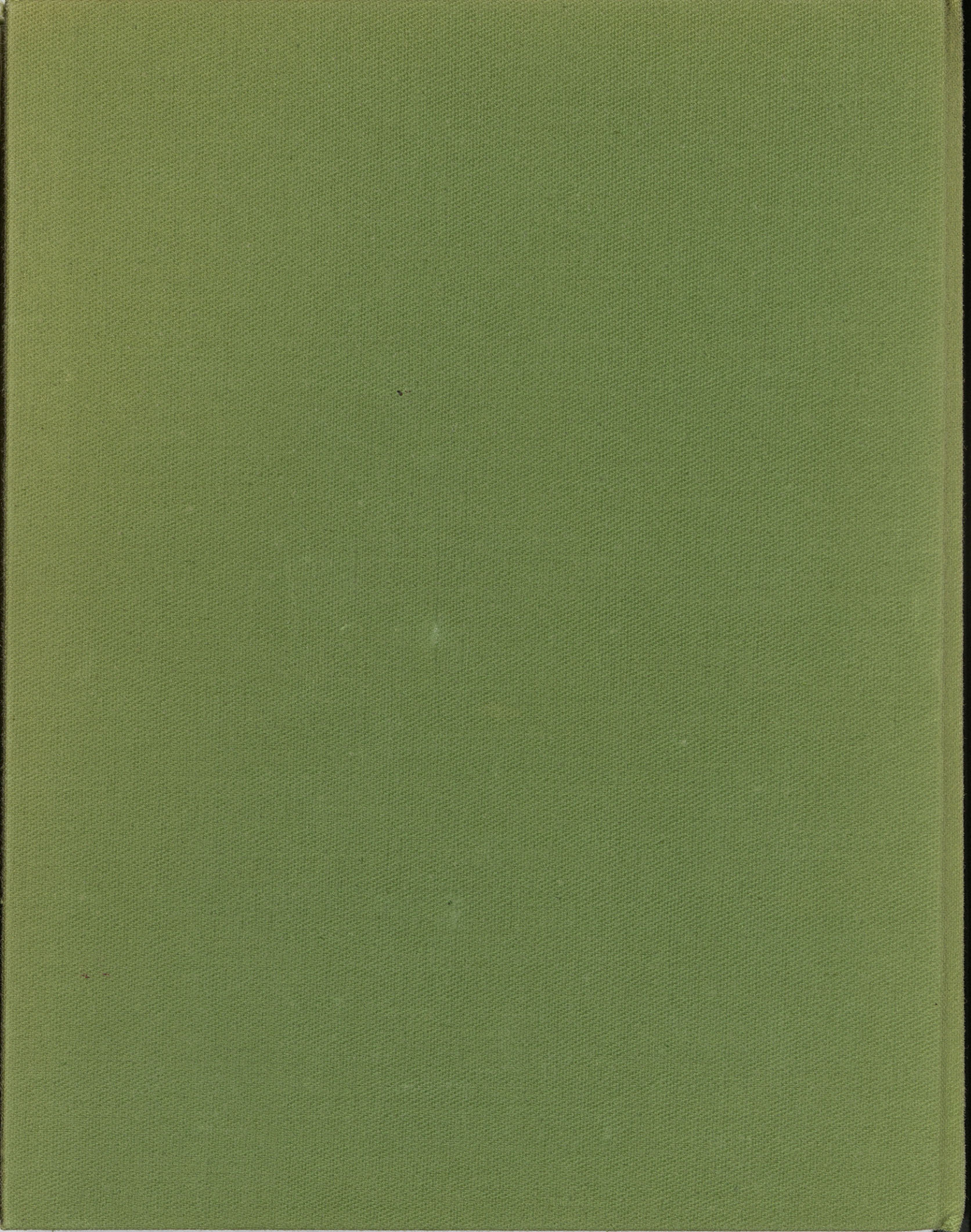
12/31/64 Got off reply to Satchel & also some reprints. Toothache now under control with aspirin & Darrow, but this undoubtedly was a major factor in reducing productivity of past few weeks.

Also received & read Gordon's histological manuscript & passed this on to Wade Marshall 12/29/64, to review & check with grand Pasumner & Paul Maclean









**TRAVEL VOUCHER**  
MEMORANDUM

DEPARTMENT, BUREAU, OR ESTABLISHMENT <b>DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE, PHS</b>		VOUCHER NO.
PAYEE'S NAME <b>Wilfrid Rall</b>		PAID BY
MAILING ADDRESS <b>National Institutes of Health Building 31 Room 9A-20 Bethesda, Maryland 20014</b>		
OFFICIAL DUTY STATION <b>Bethesda, Maryland</b>	RESIDENCE	
FOR TRAVEL AND OTHER EXPENSES FROM (DATE) <b>11/11/64</b> TO (DATE) <b>11/13/64</b>		TRAVEL ADVANCE <b>-0-</b> Outstanding \$
APPLICABLE TRAVEL AUTHORIZATION(S) NO. <b>PHS-3-75483.1</b> DATE <b>11/9/64</b>		CHECK NO.
Amount to be applied		
Balance to remain outstanding \$		

**TRANSPORTATION REQUESTS ISSUED**

TRANSPORTATION REQUEST NUMBER	AGENT'S VALUATION OF TICKET	INITIALS OF CARRIER ISSUING TICKET	MODE, CLASS OF SERVICE, AND ACCOMMODATIONS *	DATE ISSUED	POINTS OF TRAVEL	
					FROM-	TO-
<b>A5,154,977</b>	<b>\$12.78</b>	<b>PRR</b>	<b>Coach</b>	<b>10/30</b>	<b>Washington, D. C. and</b>	<b>Philadelphia, Pa. return</b>

**Physicist**

AMOUNT CLAIMED →

Dollars	Cts
<b>\$65 00</b>	

APPROVED (Supervisory and other approvals when required)

DIFFERENCES:

**F. L. Mills, Assistant Executive Officer, NIAMD**

NEXT PREVIOUS VOUCHER PAID UNDER SAME TRAVEL AUTHORITY		
VOUCHER NO.	D.O. SYMBOL	DATE (MONTH-YEAR)

Total verified correct for charge to appropriation(s)

Applied to travel advance (appropriation symbol)

NET TO TRAVELER →

**65 00**

ACCOUNTING CLASSIFICATION (Appropriation symbol must be shown; other classification optional)  
**384-34001-04 (2110)**

\* Abbreviations for Pullman accommodations: MR, master room; DR, drawing room; CP, compartment; BR, bedroom; DSR, duplex single room; RM, roomette; DRM, duplex roomette; SOS, single occupancy section; LB, lower berth; UB, upper berth; LB-UB, lower and upper berth; S, seat.



10/26/64

Question: since it is probable that paper II will appear significantly later than paper I, perhaps we should say a little about granule & axon & present one tentative reconstruction.

Why not?

page 1 & 2 led line? deeper

Consider also Fig. 1-B

or put 4 on other side

Blocked mitral gives <sup>extrall</sup> peak  $\approx 0.30$

The purpose of this brief note is to draw attention to the possible mutual significance of two ~~recent~~ different ~~Aspects~~ lines of recent neurophysiological research. One is the theoretical study of spatio-temporal patterns of synaptic excitation and inhibition delivered to dendritic trees (Rall, 1964). The other is the experimental demonstration of spatio-temporal ~~pattern~~ selectivity in the responses of ganglion cells in rabbit retina (Barlow, Hill, Levick, 1964).

Case	9045	9041	9141	9241	?
NJD	10	5	10	10	10
$\Delta L_D$	40 $\mu$	80 $\mu$	40 $\mu$	40 $\mu$	40 $\mu$
$\Delta L_A$	40 $\mu$	80 $\mu$	80 $\mu$	80 $\mu$	40 $\mu$
UA	25	25	25	25	25
UD	100	100	400	400	400
USA	2.5	5	5	5	2.5
USD	100	200	400	200	200
$\Delta Z_D$	.1	.1	.05	.05	.05
$Z_{LD}$	1.0	0.5	0.5	0.5	.5
$\Delta Z_A$	.2	.2	.2	.2	.2
$Z_{LA}$	.6	.6	.6	.6	.6

assuming  $G_D = G_{SD}$

$\frac{CD}{CS} = \frac{USD}{UD}$	1	2	1	$\frac{1}{2}$	$\frac{1}{2}$
----------------------------------	---	---	---	---------------	---------------

$\frac{G_D}{G_A} \approx \frac{G_{SD}}{G_{SA}} = \frac{USD}{USA}$	40	40	80	40	80
---	----	----	----	----	----

assuming $G_A = G_{SA}$					
$\frac{CA}{CS} = \frac{USA}{UA} =$	$\frac{1}{10}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{5}$	$\frac{1}{10}$



## Introduction

Part I - Electrophysiological Records to be Analyzed

Part II - Theoretical Significance of Punctured Symmetry

Part III - Response <sup>Computed</sup> Deduced for Mitral Bodies & Dendrites

Figs 5 & 6

Part IV - Latencies and Gradients of ~~Mitral~~ <sup>Deduct</sup> for Mitral Model

Figs. 7 & 8

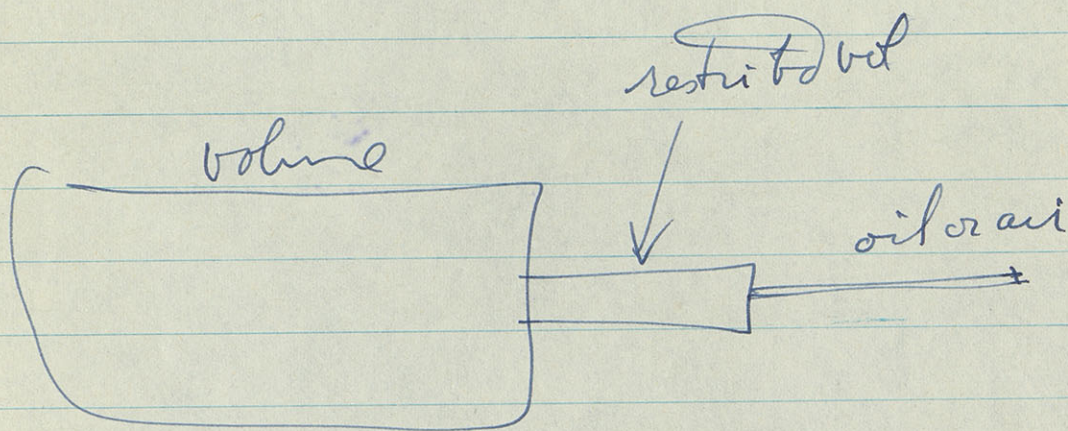
Part V - Discussion

see p. 86 of Book 4

question of hydraulic  
axonal  
conductance

remembers also my thesis  
input monitor

This could  
be checked  
with a  
nerve  
trunk  
exp.



may have to try with trunk

Write a review for Exp. Neurol.

Also, could use some of this in Cal. Tech introd.

In this paper, I wish to ~~trace~~  
review the revolution that has  
been taking place in neurophysi-  
cal thinking about dendrites. My  
own ~~studies of dendritic~~ ~~fund~~  
~~properties~~ began in 1956  
with a consideration of their  
cable like properties. These  
~~early studies~~ led to  
at this time, there was  
a rather authoritarian neurophysi-  
ologist (which, now, in 1964, seems  
already hard to believe)

## Introduction:

(A short introduction will be added to the final draft. Here is a tentative stab at this.)

### Neurophysiologist.

~~One~~

An important objective of much neurophysiological research is to understand ~~the relationship between~~ how ~~transients of electric potential~~ the experimentally recorded transients of electric potential

This rese.

This paper presents the results of an effort at a theoretical reconstruction of ~~the~~ experimentally recorded potentials, as a function of time and of depth in the olfactory bulb.

See semi-annual report.

What is the relation

When the response of a population of  
neurons ~~is~~ is ~~recorded~~ experimentally  
recorded as the transient

→ under experimentally  
reproducible conditions, it is

9064 error in BEB

↑  
notice that dandrater first nearsynchrony  
caused inverted extracellular  
picture

possibly occur this erroneous  
loss without antidromic & with  
loss some fail to reduce  
synchrony.

$$VEF = 40$$

Program could treat end of. differently (choose C so that  
 $\text{UDT}_{\text{terminal}} = 2. * \text{UD}$ )

9041, 9061 series needs to be redone  
with SHCF = 0.

to compare with SHCF = 0.5  
& 0.2

X 3.1

This deals with old Fig. 3 which is now postponed.

Fig. 3.1

A more quantitative description of the direction and magnitude of extracellular current flow during mitral invasion is afforded by the graphs in Fig. 3. Here the potentials at different depths in the bulb are plotted for certain instants of time. The graph in the left covers three instants of time during Period I of Fig. 2; the graph on the left covers the time from the end of Period I through Period II.

The earliest instant of <sup>significant</sup> non-uniformity in the mitral membrane potential due to the invading antidromic impulse occurs at 1.2 msec, when the extracellular potential begins to move negative at the mitral somatic ~~curve~~ <sup>a</sup> (C in Fig 2) and positive at the dendritic termini (A in Fig. 2). This potential difference is heightened at 1.6 msec, with a correspondingly steep gradient of potential all along the dendritic shafts (slight irregularities can be neglected, as due to <sup>unitary</sup> responses superimposed on the wave responses). A similarly steep gradient occurs at 2.0 msec, when the negativity at the somata is near its peak, and even the dendritic periphery is at a negative extracellular potential.

A conventional interpretation of these events is that these times cover the progressive invasion of the antidromic impulse into the mitral cell body<sup>ies</sup>, which are increasingly sinks <sup>for</sup> ~~&~~ extracellular current flow. The dendrites are corresponding sources for these sinks, being at more positive (or less negative) extracellular potentials. Note that the dendrites are sources even at negative potentials; the polarity of an extracellular potential

Slight artefact contribution

?

?

?

o



has no necessary relation ~~to~~ to whether it is a source or a sink of extracellular current flow. We will show below that the positive polarity of the dendritic periphery can be merely an artifact of the recording set-up.

We thus conclude that at every point along the dendritic shafts from 1.2 to 2.0 msec., current is flowing ~~constantly~~ <sup>outward</sup> through the dendritic membrane, depolarizing it. Whether this depolarization is purely passive, or whether it includes a regenerative response of the dendritic membrane, is the question which the mathematical model will attempt to answer.

The transition between Period I and Period II occurs at about 2.2 msec. as shown in the right-hand graph of Fig. 3. At this instant the dendritic periphery is continuing to depolarize while the mitral somata are beginning to repolarize. There is consequently no consistent potential gradient along the mitral cell, and hence little extracellular current flow. At 2.6 msec. the potential gradient is just opposite to that at 1.6 msec., because the repolarizing somata are now more positive, and hence current  $\phi$  sources, ~~to~~ <sup>for</sup> the still depolarized dendritic periphery. As the activity of the mitral g.e.c. dies away, the potential nonuniformity along the dendrites disappears. The extracellular potentials fall toward baseline, and at the end of the period, at 3.6 msec, the potential curve would be at baseline, with no extracellular current flow, except that now a new potential gradient is beginning because of the action of the granule g.e.c. (Rall and Shepherd, 1965).

How about  
synaptic dendritic  
spike  
no, this  
applies really  
to period II

Resumes ? 9041 + 9044

to have smaller dendritic  
steps.

---

Passive

5 dendritic  
terminal peak  $\approx 0.45$

10 dendritic  
terminal peak  $\approx 0.25$

flat facilitation as good or better than shaped eg. 9031 inferior to 9041  
except for <sup>shape of</sup> rise of soma spike

facil E should be avoided at soma cft.  
importance of control without antidromic

NJD = 5  
Period II should be  
better  
(handplot .9043)

NJD = 10  
Period II appears  
very slow  
(corresp. - soma spike back to zero  
with terminals atten. peaks)

Ve initial artefact is least when  
I.C. are flat and  
soma & peripheral Vi  
remain close together

Active

(5 or 10 dendritic cpts)

flat facil



synch. dendritic spike



$$V_e \propto \frac{dV_i}{dt}$$

small amplitude

shaped facilitation (most at soma)



propagated dendritic spike



$V_e$  resembles difference  
(nearly equal + & -)  
larger amplitudes

? minimum & intermediate depths

---